PHASE I - INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

7

CASTLE ROCK RESERVOIR DAMS

ROSEBUD COUNTY, MONTANA

MAIN DAM MT - 1982 SADDLE DAM MT - 3146

PREPARED FOR:

HONORABLE TED SCHWINDEN

GOVERNOR, STATE OF MONTANA

AND

MONTANA POWER COMPANY

OWNER / OPERATOR

PREPARED BY:

Christian, Spring, Sielbach & Associates

Bozeman, Montana

Assisted By:

Northern Testing Labs, Inc.

Great Falls, Montana

June 1981

Seattle District

United States

Army Corps of Engineers

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EXECUTIVE SUMMARY

Personnel of Christian, Spring, Sielbach & Associates, principal contractor, and Northern Testing Laboratories, Inc., subcontractors, under a contract with the Montana Department of Natural Resources and Conservation (MDNRC) and with representation from the Montana Power Company and the MDNRC, inspected Castle Rock Reservoir and its Main and Saddle Dams on August 7, 1980, under the authority of Public Law 92-367. The project is located principally in Section 28, Township 2 North, Range 41 East, MPM, offstream of Armell's Creek in Rosebud County, Montana, less than ½ mile NW of the town of Colstrip, Montana.

This report was compiled from information obtained during the onsite inspection, review of Bechtel Corporation design reports, construction plans, and analysis of available information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction and operation.

FINDINGS AND EVALUATIONS

The Castle Rock Main and Saddle Dams and appurtenances were constructed in 1975 by the Montana Power Company with engineering design and construction management services provided by the Bechtel Power Corporation. The project is owned and operated by the Montana Power Company. The reservoir provides reserve cooling water storage for a coal-fired generating complex at Colstrip. It is also used for recreational purposes.

The 67-foot-high Castle Rock (Main) Dam and 19-foot-high Castle Rock (South) Saddle Dam impounds approximately 3540 acre-feet of water at common dam crest elevation 3288.5 feet National Geodetic Vertical Datum (NGVD). Elevations are based on levels taken during the inspection and using elevation 3290.0 feet at the south corner of the south wingwall at the entrance to the emergency spillway as a temporary benchmark. On the basis of criteria in the U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the project is intermediate in size.

The sudden failure of either dam impounding Castle Rock Reservoir would cause flooding in the town of Colstrip and result in extensive property damage and endangering of many lives. However, no dam breach analysis or routing of a dam breach flood was made for either dam. The conclusions on probable damage are based on a brief field visit and engineering judgment. The project is classified as having a high (Category 1) downstream hazard potential.

Inspection criteria (Ref. 1) recommend that an intermediate size project with a high downstream hazard potential be capable of safely handling the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. The estimated PMF for the 0.89 square mile drainage basin resulted from a 72-hour general storm probable maximum precipitation (PMP) developed for this dam safety study. The resultant PMF has an estimated volume of 1,370 acre-feet.

The maximum discharge capacity of the emergency spillway with the reservoir at dam crest elevation 3288.5 feet NGVD is 2,820 c.f.s. For routing studies of the PMF the initial reservoir elevation was assumed to be at the spillway crest elevation 3281.0 feet NGVD. The studies show the Castle Rock project successfully passes the PMF without overtopping. The maximum water surface elevation during the PMF routing without flashboards was found to be 3286.2 feet NGVD, which is more than 2 feet below the minimum dam crest elevation 3288.5 feet NGVD. Maximum spillway outflow was found to be 1,614 cfs. With flashboards in place to elevation 3285.0 feet NGVD and reservoir elevation at 3281.0 feet NGVD at the beginning of the PMF, the maximum reservoir level attained during the routing was found to be 3287.5 feet NGVD, one foot below minimum dam crest. Additional routings were made with the reservoir initially at the flashboard crest elevation 3285.0 feet NGVD. Routings indicate that the full PMF developed for this inspection slightly overtopped the low point in the dam crest for a short period of time. Because of the remote possibility of this scenario and the conservative nature of the input data used in the routing, we do not feel additional studies are warranted. However, this information is displayed to guide future operations of the reservoir.

The visual inspection of the Main dam embankment revealed neither longitudinal or transverse cracking, settlement, or misalignment. The exposed upstream slope above reservoir water level (elevation 3279.3 feet NGVD) exhibited profile irregularities. Portions of the upstream slope had been steepened and benched, apparently during the construction of the slurry wall after the original dam was completed. Slope cross section and riprap were not restored to their original lines. The steepened baked shale (scoria) covered upstream slope at the left abutment deviates from the original design, but appears stable. Wave erosion is undercutting the saddle-service road between the left abutment and the emergency spillway. Although this does not endanger embankment stability, protective measures to prevent further undercutting should be installed. Precipitation runoff has caused some erosion at the downstream left abutment contact and minor rilling on the downstream slope. The slope is well protected with grass cover except for a few small areas. The concrete slurry trench cutoff has substantially reduced seepage through the right abutment.

The visual inspection of the Castle Rock Saddle Dam revealed no settlement, misalignment, or cracks. Slopes were generally uniform with the upstream slope well covered with riprap. The downstream slope had a good cover of grass. No seepage was noted at the toe or abutment contacts, and the toe drain was dry.

The concrete emergency spillway was observed to be in good condition with no evidence of settlement, serious cracking, or spalling. The pipe drains for the "flip bucket" outlet were apparently plugged as water was standing in the flip bucket and phreatophytes were growing. Some erosion of earth materials adjacent to the chute sidewalls, around the wingwalls at the outlet, and immediately downstream from the flip bucket has occurred. This erosion is apparently caused by precipitation runoff in and adjacent to the chute, since no spillway flows have occurred. Because of the high erodibility of the soils, spillway flows could undermine the slab and support piles at the spillway outlet. However, such erosion would not endanger the dam since a natural ridge separates the spillway and the Main Dam embankment.

The design analysis procedure and criteria for stability of the Main and Saddle Dam embankments and foundations used by Bechtel are in accordance with the Recommended Guidelines for Safety Inspection of Dams (Ref. 1). Factors of safety obtained meet or exceed the criteria. Based on our review of project design information and our visual inspection, it is our judgment that dam embankment stability of both the Main Dam and Saddle Dam may meet recommended guideline criteria. Seepage through the abutments and foundation of the Main Dam appears to have been reduced to very small quantities, however, monitoring of piezometers and observation wells should be continued. With maximum reservoir levels maintained at or below elevation 3284.0 feet NGVD, it is our judgment that available surcharge storage and spillway discharge capacity are adequate to handle possible flood flows.

The outlet works and supply pipe under the Main Dam embankment could not be inspected during the site visit because of water levels in the reservoir. However, since the outlet works operate continuously any malfunction would be noted immediately. Routine inspection should be made to monitor condition. No formal downstream warning plan is in effect.

Recommendations

The intent of report recommendations is to maintain the project safety and to improve structural integrity. A downstream warning plan, for use in the event of dam distress, should be developed and immediately placed in action.

For the Main Dam:

Inspect the outlet works conduit beneath the dam embankment and make repairs if necessary. Repair erosion damage along emergency spillway chute sidewalls, and at the outlet of the concrete chute. Repair runoff erosion damage on the downstream left abutment contact and along the downstream toe of the embankment. Provide riprap or other wave protection along the saddle-service road between the left abutment and the emergency spillway.

For the Saddle Dam:

Consider restoration of dam crest elevation to a minimum elevation of 3289.0 feet NGVD at all points on top of dam profile.

For Both Dams:

Continue to periodically monitor the downstream piezometer levels. Implement a program to control burrowing animals.

Conduct periodic inspections of the project dams at no less than 5-year intervals by engineers experienced in dam design and construction.

Bob B. Gemmell
Professional Engineer

CASTLE ROCK DAMS
PERTINENT DATA

General	
Federal I.D. No. (Main Dam)	MT-1982
Federal I.D. No. (South Saddle Dam)	MT-3146
Owner/Operator	The Montana Power Company, Inc.
Date Constructed	1975
Purpose	To provide reserve cooling water storage (18-days in summer, 24-days in winter) for 4 coal-fired power generating stations. Also, to act as a surge pond for cooling water pumped from the Yellowstone River some 35 miles to the north
Location	Sec. 28, T2N, R41E, MPM Rosebud County, Montana ½ mile NW of Colstrip, Montana Latitude 45°53.6' Longitude 106°38.4'
Watershed	Offstream of Armell's Creek a tributary of the Yellowstone River
Drainage Area	0.89 square miles (including reservoir)
Size Classification	Intermediate
Downstream Hazard Classification	Category 1 (High)
Reservoir (Common to Both Dams)	
Storage at summer normal/maximum pool & emergency spillway crest elevation 3281.0 feet NGVD	2280 acre feet
Reservoir (Continued)	
Surface area at normal pool	140 acres
Storage at winter maximum pool & emergency spillway flashboard crest elevation 3285.0 feet NGVD	2930 acre-feet
Storage at Saddle Dam crest elevation 3288.5 feet NGVD	3540 acre-feet
Reservoir Elevation (8/7/80)	3279.3 feet NGVD
Emergency Spillway (Common to Both Dams)	
Type	Uncontrolled Reinforced Concrete Chute
Crest Elevation	3281.0 feet NGVD
Length of Crest	36 feet
Capacity at Saddle Dam Crest elevation 3288.5 feet NGVD	2820 cfs.

CASTLE ROCK DAMS
PERTINENT DATA

Winter Modifications

Type	4 foot high flashboards installed on top of ogee crest
Crest Elevation	3285.0 feet NGVD
Length of Crest	36 feet
Width of Crest	2.5 feet
Capacity at Saddle Dam crest elevation 3288.5 feet NGVD	850 c.f.s.

Outlet Structure

A reinforced concrete tower houses the inlet and controls for the 48 inch steel conduit to the power station cooling system. The conduit is encased in concrete as far as the downstream toe of the dam.

Dam Embankments	Main Dam	Saddle Dam
Type	Zoned rolled earth with grout curtain and concrete slurry wall	Zoned rolled earth
Hydraulic Height	67 feet	19 feet
Crest Elevation	3289.0 feet NGVD	3288.5 feet NGVD
Crest Length	1095 feet	800 feet
Crest Width	20 feet	20 feet
Upstream Slope	1V on 3.5H	1V on 2.5H
Downstream Slope	1V on 2.5H	1V on 2.5H

CHAPTER 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Castle Rock (Main) Dam, and Castle Rock (South) Saddle Dam near the city of Colstrip in Rosebud County, Montana. The project is owned and operated by the Montana Power Company, Inc.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers to conduct safety inspections on non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May, 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary the guidelines recommend a two-phase study procedure for investigation and evaluation of existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety and condition of the dam.
(2) based upon an evaluation of the available data and a visual inspection.
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted.
(4) not intended to include extensive explorations, analysis or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analysis.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended

only to evalute project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the State of Montana and the dam owner. It should be noted that nothing contained in the National Dam Inspection Act, and action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership and operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify current physical and operational conditions of the dam and appurtenances; and to determine if emergency measures and/or additional studies, investigations, and analyses are needed, so that corrections can be made in a timely manner by non-federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a review of available engineering data, records, design reports, construction drawings of Castle Rock Reservoir Dams and a visual inspection of the project. Design information and construction drawings were obtained from the home office of the Montana Power Company in Butte, Montana. Inspection procedures and criteria used for this report were those established by the Recommended Guidelines for the Safety Inspection of Dams. (Ref. 1)

The inspection was conducted jointly by personnel from Christian, Spring, Sielbach & Associates and Northern Testing Laboratories, Inc., subcontractors. Personnel who participated in the field inspection and contributed to this report were:

CSSA- Bob B. Gemmell, Engineer, Team Leader
Alfred Cunningham, Hydraulics/Hydrology (report only)
Les Crawford, Civil Engineer
Kent Sielbach, Surveyor

NTL- Robert Gillespie, Geotechnical Engineer (report only)
Bill Henning, Geologist
Gary Quinn, Geotechnical Engineer

MDNRC- Montana Department of Natural Resources and Conservation
Art Taylor, Dam Safety Engineer

Other personnel present and participating in the field inspection include:

The Montana Power Company
John Pack, Engineer
Denise Towee, Engineer

This report has been reviewed by The Montana Power Company and the State of Montana DNRC and their written comments are enclosed in Appendix A.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

a. Location, Owner and Purpose

Castle Rock Reservoir is located offstream of Armell's Creek principally in Section 28, Township 2 North, Range 41 East, MPM, in Rosebud County, Montana. (Plate 1) The reservoir impoundment is formed by two dams having a common spillway and outlet works. The reservoir is less than one-half mile northwest of the City of Colstrip. (Plate 2) Castle Rock Dam is located in SE¼ of Section 28 and Castle Rock Saddle Dam is located in the NE¼ of Section 33. The Federal identification number for Castle Rock Dam is MT-1982, and for Castle Rock Saddle Dam is MT-3146. Both dams are listed as having a high (Category 1) downstream hazard potential.

The dams are owned and operated by the Montana Power Company. The project was planned for use as both a surge pond and a reserve storage facility for cooling water to be used in the 2200 MW coal-fired power generating plant now under construction at Colstrip. The cooling water which passes through the project is pumped through a pipeline from the Yellowstone River near Forsyth, Montana, about 35 miles to the north. The Bechtel Power Corporation designed the project and provided construction management services when the project was constructed in 1975.

b. Description of Dams and Appurtenances

The Castle Rock Dams are zoned earth-filled structures using soil materials primarily from local borrow areas. The Main Dam embankment has a height of 67 feet from downstream toe to dam crest. The Saddle Dam has a height of 19 feet from toe to crest. The Main Dam has a grout curtain and a concrete slurry wall installed to control seepage. All elevations in this report are based on an assumed elevation of 3290 feet NGVD at the south corner of the south wing wall of the emergency spillway. The Main Dam crest is at 3289.0 feet NGVD. The Saddle Dam crest is generally at 3289.0 with a low elevation of 3288.5 feet NGVD. This is the lowest point in the reservoir boundary and is therefore used as dam crest throughout this report. The reservoir will impound 3540 acre-feet at dam crest elevation 3288.5 feet NGVD and 2280 acre-feet at emergency spillway crest elevation 3281.0. The surface area of the reservoir with the water level at spillway crest elevation is about 140 acres. The total drainage area including reservoir surface is 0.89 square miles.

The emergency spillway is a reinforced concrete chute with an uncontrolled ogee crest 36-feet-wide. The cast-in-place concrete structure is set into native soil material and bedrock approximately 200 feet northwest of the left or north abutment of the Main Dam. A large knoll separates the unlined emergency spillway exit channel from the main dam embankment. A cast-in-place concrete tower located about 150 feet into the reservoir near the right abutment of the Main Dam serves as a drop-inlet for the outlet works. Discharge to the power plant cooling system is through a 48-inch diameter welded steel pipe, the first 160 feet of which is encased in concrete with the remainder "installed as a free standing pipe in an 8-foot diameter concrete conduit." (Ref. 8)

c. Hazard Potential

Based on visual reconnaissance and engineering judgment, Castle Rock Reservoir is located such that a sudden breach of either dam could endanger many lives and cause extensive property damage in the downstream area. (Plate 3) The Colstrip water treatment plant sits at the downstream toe of the Main Dam embankment. Residential areas and the Colstrip sewage treatment plant are all less than 3,000 feet downstream of the Saddle Dam. Montana Highway 39 and a Burlington Northern Railroad coal mine spur cross both the Main and the Saddle Dam drainages within 3,000 feet of the embankments. On the basis of this information and in accordance with recommended guidelines, the Castle Rock project's size is intermediate and the downstream hazard potential is high (Category 1).

1.2.2 Regional Geology

The Castle Rock Main and Saddle Dams are located within the Northern Powder River Basin. The major geologic units within the Basin consist of late Cretaceous Marine deposits and continental deposits of late Cretaceous to Holocene age.

The Cretaceous age was characterized by frequent transgressions and regressions of the large Continental Sea, possibly related during late Cretaceous time to the beginning of the Laramide Orogeny. Broad regional uplift in Central Montana is believed to have been a cause of the final withdrawal of the sea. Vast amounts of continental deposits indicative of various fluvial and lacustrine environments were then deposited. Extensive swamps existed at various periods throughout the Late Cretaceous to Eocene time, and are now represented by many coal beds of various thicknesses and lateral extent in the Hell Creek, Fort Union, and Wasatch Formations.

Fort Union sediments were deposited during the Paleocene as the Bighorn Mountains and the Black Hills began to rise, and large volumes of sediments were transported into the nearby floodplain environment of the newly formed Powder River Basin.

The upper Paleocene is represented in the depositional sequence in the basin by the Tongue River Member of the Fort Union Formation. This unit is alternating sandstone, siltstone, carbonaceous shale, coal and clinker.

Tectonic events that occurred from Late Cretaceous through Pliocene time shaped the Powder River Basin into its present structure.

By Eocene time all major structural features of the area had been partly formed and Wasatch Formation sediments were being deposited. During early Eocene time, strata in the basin and surrounding areas were strongly folded and faulted, forming most of the present day structural features of southeastern Montana (Ref. 7).

1.2.3 Seismicity

The site lies in Seismic Zone I, a zone of generally minor seismic risk as per the Corps of Engineers Guidelines, (Ref. 1) with a seismic coefficient of 0.05.

Preliminary seismic mapping by Algermissen and Perkins indicates that there is a 90 percent probability that the horizontal acceleration in rock will not exceed 0.04g in a given 50-year period.

1.2.4 Site Geology

Castle Rock Main Dam lies across an east-west trending valley formed by downcutting of the stream through the soft shale and sandstone units of the Fort Union Formation.

Both abutments and most of the dam foundation rest on and are tied to sandstone and shale of the Fort Union Formation. The bedrock units are nearly horizontal, with minor, broad, open folding observed in a road cut near the right abutment. Two coal seams underlie the site and the surrounding areas. The sandstone and shale units, for the most part, weather easily, forming low, rounded hills on the abutments and surrounding area. Alluvium in the valley reaches a maximum depth of approximately 35 feet. Clayey silt and a few discontinuous sand and gravel lenses make up most of the alluvial material.

Both the emergency spillway and outlet conduit rest on sandstone and shale.

The Saddle Dam, built between two small knolls, is in the southeast portion of Castle Rock Reservoir, across a small valley. These knolls consist of a caprock of scoria (baked shale), underlain by sandstone of the Fort Union Formation. The sandstone is overlain by approximately 5 feet of slope debris and weathered sandstone on the sides and bottom of the small valley. The dam abutments and foundation are tied to and rest on the sandstone bedrock.

1.2.5 Design and Construction History

Between 1970 and 1971, five potential reservoir sites around Colstrip, Montana, were investigated by the Bechtel Power Corporation of San Francisco, California. In its February, 1973, report on dam sites Bechtel recommended Site 4 for detailed geological explorations. The investigations performed during March and April, 1973, included 18 test trenches, 5 shallow auger borings and 7 rotary wash borings to an aggregate depth of 430 feet in areas of the proposed dam's axis, the emergency spillway and potential borrow sites. An additional 14 rotary wash borings to an aggregate depth of 527 feet in October, 1973, were necessitated by relocation of the spillway to its present location and an enlargement of the embankment. A design report was issued in October, 1973, for Site 4 which is the current location of Castle Rock Reservoir in S28, T2N, R41E, MPM.

On March 1, 1974, the Montana Department of Natural Resources and Conservation directed that live storage in Castle Rock be increased by 1,000 acre-feet in winter months in the event that ice or very low flows in the Yellowstone River prevented pumping for as long as 50 days. To satisfy these new requirements the project was redesigned. Dam embankments were raised 5 feet and a system of 4-foot-high flashboards were added to the emergency spillway for winter use only. The Revised Design Report was issued in July, 1974. Construction began in late summer of 1974 and was completed by early 1975.

The post construction history is best described by selected quotes from the report on:

INVESTIGATION AND CONTROL OF SEEPAGE
AT THE SURGE POND DAM, COLSTRIP, MONTANA

By:
Bechtel, Inc.
April, 1977

"4.0 History of Reservoir Filling

Reservoir filling began in early 1975, and as the pool elevation rose, ground water levels in observation wells downstream and near the right abutment rose. In May, 1975, the reservoir had reached a water surface elevation of 3254 feet, and water was flowing from the collar of well GW-1 at an elevation of 3241.6 feet. At the same time a zone of saturated ground had developed, extending from the right groin of the dam toward the southeast. This saturation was apparent at and below about an elevation of 3250 feet. As the reservoir continued to rise, the abutment saturation increased, and extended further south until seepage was noted in the gully south of the pumphouse. A series of horizontal or gently inclined hydrauger drains were drilled into the saturated abutment slopes to drain and stabilize them and to facilitate collection and measurement of the quantity of seepage. By early September, the reservoir elevation was 3273 feet, and the seepage flowing from the drains had reached nearly 1000 gpm."

"By this time remedial grouting was under way, and from the behavior of the grout program it was clear that the seepage was moving through interconnected open joints in the rock of the right abutment. Since no sediment or other evidence of erosion was observed in the seepage effluent, the seepage paths were thought to lie entirely within the foundation rock, and no immediate concern for the integrity of the dam embankment seemed warranted. At the same time, grout did flow from the hydrauger drains in several cases, indicating a direct hydraulic connection between the drains and some of the grout holes very near the surface of the foundation rock."

"Early in September, 1975, pumping to the reservoir was stopped and the pool level was allowed to decline due to withdrawals for the power plant. The purpose of lowering the level was to reduce the hydraulic gradient in the open joints that crossed the right abutment, and to minimize any long term development of hydraulic conditions that might lead to erosion or piping in either the foundation or the embankment of the dam. With the lower reservoir level the quantity and velocity of water moving through the joints decreased, enabling grout to be more effectively placed in them."

"Remedial grouting measures were continued through mid-November, 1975, by which time the reservoir had been lowered to an elevation of 3258 feet. During this period, the grouting had noticeably reduced seepage from the source of the hydrauger drains, and the combined effect of the grouting and reservoir lowering had cut the total flow to less than 100 gpm. At this point it was estimated, from the grout records and data on ground water levels and seepage, that if the pond were re-filled seepage

would increase but would be significantly less than that experienced before the remedial grouting. By comparing the character of the seepage, pond level, and ground water hydrographs before, during, and after the grouting, the quantity of seepage with the reservoir full was projected to be about 300 to 500 gpm."

"Refilling of the reservoir began in December, 1975, and pool elevation reached 3280 feet in mid-June, 1976. During this period the water level was raised in 5 foot increments, and held at each stage for approximately 2 weeks to observe the effect of the head increase on ground water levels and seepage."

"Seepage increased during this period to almost 600 gpm, accompanied by re-saturation of parts of the slope southeast of the right abutment. At this point the seepage at full reservoir (elevation 3285 feet) was projected to be greater than 800 and possibly over 1000 gpm. At the end of June, 1976, it was decided to lower the reservoir to an elevation of 3275 feet and review all data before recommending final action."

"5.0 The Consulting Board

In July of 1975, a three member consulting board was retained, including Keith E. Anderson, ground water specialist, Karl V. Taylor, Bechtel executive engineer, and Charles S. Content, Bechtel executive geologist. In November, 1975, Thomas M. Leps, consulting engineer, joined the board.". . ."The source and pathway of the seepage was determined by exploratory drilling, installation of piezometers, resistivity surveys and remote sensing studies.". . ."The decision to install a concrete slurry wall cutoff was reached in August, 1976, after the alternative of operating the reservoir at a reduced elevation and accepting some seepage was rejected.". . ."Immediately following the August 23 board meeting, the owners authorized construction and several contractors were contacted to obtain proposals and cost estimates. ICOS Corporation of America was selected for the work because of their experience in designing and construction concrete slurry walls under similar geologic conditions."

"7.3 Chronology of Wall Construction

Actual construction of the wall began during the week of September 30, 1976, with the stripping of about five feet of the crest of the dam between station 19+00 and station 21+00 to provide a broad work area on the crest and permit the installation of the concrete guide walls.". . ."With the pouring of S-12 on December 3 the weir box stopped flowing altogether. On December 9 the last panel, S-14, was completed. The seepage flow measured at the flume near the toe of the dam (flume #1) was less than 2 gpm.". . ."Remedial grouting, under operating reservoir conditions, reduced the seepage to approximately 600 gpm and seepage was almost entirely eliminated by constructing 340 lineal feet of concrete slurry wall cutoff to a depth of from 61 to 69 feet in the right abutment.". . ."The ICOS concrete slurry wall was an effective cutoff because the critical seepage zones had been defined through successive geologic investigations and remedial action. By the time the wall was installed, the seepage mechanism was well enough understood to permit construction of the minimum length and depth of wall that would still cut off the most significant paths of seepage."

"As of February 28, 1977, the reservoir had been raised to elevation 3283.4 feet, or nearly to its maximum operating pool level. Surface leakage from the right abutment drains was less than 1.9 gpm. Ground water levels measured in piezometers on the upstream side of the wall have consistently risen with filling of the reservoir, while those downstream but close to the wall have shown declines of several feet."

In the four years since the construction of the slurry trench, seepage has been minimal if not nonexistant and the project history has been uneventful.

In about 1976 an earth dike was placed about 30 feet in front of the emergency spillway. This would prevent winter ice on the reservoir from exerting pressure on the flashboards. The dike's crest is at elevation 3285 feet NGVD, the same as the flashboard crest. The dike forms a semi-circle with a radius of about 30 feet around the spillway entrance, so that water must pass over the dike to enter the spillway. However, the dike does not significantly affect spillway flows with the flashboards in place.

CHAPTER 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Outlet Works

The inlet structure for the outlet works for Castle Rock Reservoir is an 80 foot tall, 13 foot square concrete tower. (Plate 8) The 6 foot by 40 foot trash racks on three sides, from elevation 3240 feet to 3280 feet, allow flows to enter the hollow core of the structure. Discharge is through a 48-inch diameter welded steel pipe. This pipe is encased in concrete for the first 160 feet to the cutoff trench of the main dam embankment. From there it is installed as a free standing pipe in an 8-foot diameter concrete culvert. The outlet conduit is set about seven feet into bedrock near the right abutment. Flows are piped directly into the power plant's cooling network and the City of Colstrip's water treatment plant. Water levels at the time of inspection prohibited inspection of the outlet works.

Since the controlled outlet works discharges only to the Colstrip water treatment plant and to the power plant cooling system, it does not affect flood routing. The outlet works is operated and monitored on a continuous basis, so operational difficulties would be immediately noted by operations personnel.

2.1.2 Emergency Spillway

The emergency spillway for the Castle Rock Reservoir dams is a reinforced concrete chute located on the left abutment approximately 200 feet north-west of the north end of the Main dam. (Plate 9) The entrance to the spillway is an uncontrolled ogee section with a crest length of 36 feet. Sidewall height at the ogee crest is 9 feet. The spillway terminates in a flip bucket with the end sill at an elevation well above the bottom of the excavated stilling basin energy dissipator. (Photo 1) Provisions have been made to install flash boards at the spillway entrance to increase storage in winter months. (Plate 10) The flashboards were in place at the time of the field inspection. (Photo 2)

The crest of the spillway ogee section is at elevation 3281.0 feet NGVD. The top of the flashboards is at elevation 3285.0 feet. The chute has a bottom gradient of approximately 0.20 feet per foor for 80 feet to the flip bucket. The impact area immediately downstream from the end sill of the flip bucket appears to be highly susceptible to erosion. (Photo 1) The pipe drains for the flip bucket were plugged and silt had collected in the depressed area. (Photos 9 & 10) The spillway concrete appeared to be in good condition.

The spillway discharge rating was developed with flashboards removed. The weir-head discharge relationship was used with a constant discharge coefficient of 3.9. The maximum discharge capacity of the spillway with flashboards removed and with the reservoir at the crest of the dam, was estimated to be 2820 c.f.s. A spillway rating curve is shown on Plate 11. A second spillway discharge rating was developed with the flashboards in place to elevation 3285.0 feet NGVD. The maximum discharge with the reservoir at dam crest was estimated to be 850 c.f.s.

2.1.3 Freeboard

Flood routings with initial reservoir level at the spillway crest elevation 3281.0 feet (see paragraph 2.2.4) indicated that the maximum water surface elevation attained during the routing of the PMF was 3287.75 feet NGVD providing about one (1) foot of freeboard with the recommended SDF. The vertical distance between the low point on the Saddle Dam and the reservoir level of 3279.3 feet NGVD at the time of the August 7, 1980 inspection was about 9.2 feet. Under normal operations reservoir levels fluctuate almost daily, however, normal pool elevations will rarely be above 3284.0 feet, 4.5 feet below the low point on the dam crest. At the time of inspection, high water marks were observed at about elevation 3282 feet NGVD. However, MPS personnel present reported the reservoir had been filled to an elevation of about 3284 feet NGVD during the previous winter. The effective fetch for wind-generated waves on the reservoir is less than one mile, and wave runup on the embankment is estimated to be less than 3.0 feet. The vertical distance between the crest of the dam and normal reservoir level is adequate to prevent overtopping of the embankment by wind-generated waves.

2.2 HYROLOGY

2.2.1 Physiography and Climatology

The Castle Rock Dam and reservoir are located in Section 28 and 33, Township 2 North, Range 41 East, in Rosebud County approximately ½ mile northwest of the town of Colstrip (latitude 45° 53', longitude 106° 39'). Elevation of the dam crest's lowest point is 3088.5 feet NGVD. This off-stream storage facility receives water via pipeline from the Yellowstone River for the purpose of furnishing reserve cooling water for the coal-fired power plant located on Armell's Creek 0.5 miles southwest from Colstrip. The site is located in what is commonly known as the Great Plains of Montana, which is characterized by flat, treeless, expanses and large, gently rolling hills.

The climate in this region of Montana (Ref. 3) is commonly considered "continental" and therefore typical for the interior of a large land area. Weather in this region is highly variable with rapid changes brought on by the invasion of large air masses from the Gulf of Mexico, the south and southwest, the north Pacific Ocean, and the Polar regions. Montana is in the westerly wind belt throughout the year with the result that much of its weather comes from the west and northwest. Temperature variation in this region is extreme with summer highs in the upper nineties and winter lows down to about minus thirty degrees Fahrenheit. The average "freeze-free" season for the Castle Rock location is about 120 days ranging from about mid-May to mid-September. Average annual precipitation ranges from 14-16 inches with heavy amounts occurring from summer thunderstorms. Annual average lake evaporation at this site is about 49 inches.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a storage capacity of 2280 acre-feet at spillway crest, (normal pool) elevation 3281.0 feet NGVD and 3540 acre-feet at dam minimum crest, elevation 3288.5 feet NGVD. Approximately 1260 acre-feet of surcharge storage is available in the reservoir between the emergency spillway crest and the dam crest. With flashboards in place, and with

crest elevation at 3285.0 feet NGVD, there is approximately 600 acre-feet of storage in the reservoir between the flashboards crest and the dam crest. The maximum discharge of the emergency spillway without flashboards is 2820 c.f.s. (230 acre-feet per hour); and with flashboards in place is 850 c.f.s. (70 acre-feet per hour), with the reservoir at dam crest.

2.2.3 Estimated Probable Maximum Flood (PMF)

The probable maximum flood (PMF) is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

The PMF for Castle Rock Reservoir was developed using the HEC-1 Flood Hydrograph Dam Safety Computer program. (Ref. 4) Primary program input consisted of the 72-hour probable maximum precipitation (PMP) which was obtained for the study site from Ref. 10. The 24-hour, 10 square mile PMP value was determined from Ref. 10 to be 25.0 inches. PMP values for durations of 1, 2, 3, 4, 5, 6, 12, 24, 48 and 72 hours were also determined from Ref. 10 and used to plot a depth duration curve. This curve was used to find one hour incremental PMP values which were subsequently arranged in their critical sequence according to Ref. 5. Total precipitation for the 72-hour period was 28.25 inches and the maximum hour value was 13.06 inches.

Because Castle Rock Reservoir is an "off-stream" storage facility the contributing drainage area is extremely small (.89 square miles). As a result the maximum reservoir surface area (.33 square miles) covers nearly one-third of the entire drainage area. Under these conditions it appears reasonable to assume that the entire drainage area behaves as a reservoir during the PMP, and, therefore, no "time of concentration" for overland flow was computed. Instead it was assumed that the total rainfall during each 10 minute storm interval (i.e. total volume for .9 square mi.) enters the reservoir during that same time interval. Consequently, the unit hydrograph consists of a single value which converts rainfall (increments) into average reservoir inflow (cfs). Combination of the critical PMP sequence with the unit hydrograph ordinate resulted in the PMF inflow hydrograph to Castle Rock Reservoir. It was also assumed that frozen soil conditions prevailed during the PMP resulting in an infiltration rate of zero.

The resulting PMF volume entering Castle Rock Reservoir was was estimated at 1,370 acre-feet. "Peak" inflow with no basin time lag was estimated to be 19,160 c.f.s.

2.2.4 Flood Routing

Routing of the estimated PMF hydrograph through Castle Rock Reservoir was accomplished by means of computer program HEC-1. (Ref. 4) Since flashboards were in place on the spillway crest at time of inspection it was assumed that this condition may exist at the onset of the PMF. Under normal operating conditions, reservoir levels are most likely to be at or near 3281.0 feet NGVD. Initial reservoir surface elevation was therefore assumed to be at elevation 3281.0 with spillway discharge starting at

elevation 3285.0, the top of flashboards. Initial inflow at the onset of the PMF as well as infiltration were assumed to be zero. The modified puls method was used for reservoir routing.

Under these conditions routing studies indicate that the Castle Rock project successfully passes the most critical PMF without overtopping. The maximum reservoir surface elevation during the flood was found to be 3287.75 feet NGVD compared to minimum dam elevation 3288.5 feet NGVD. Maximum spillway outflow was computed to be about 640 cfs.

Additional routing studies were made with the reservoir at flashboard crest elevation 3285. Although there is a remote probability of this scenario, it is not an impossible one since the flashboards appear to be left in place year-round. The Castle Rock Reservoir overtopped the minimum top of dam elevation 3288.5 feet (Saddle Dam) by 0.66 feet for a short period of time.

2.3 GEOTECHNICAL EVALUATION

The "Design Report for the Colstrip Project, Montana Surge Pond Dam," (now called Castle Rock Reservoir Dams) dated 1973 October and revised 1974 July (Ref. 8), prepared by the Bechtel Power Corporation, was made available by the Montana Power Company. Also made available was Bechtel's subsequent investigation for the control of seepage following reservoir filling in 1975, entitled "Investigation and Control of Seepage at the Surge Pond Dam, Colstrip, Montana," dated 1977 April (Ref. 9).

2.3.1 Dam Embankments

The Castle Rock Reservoir was designed to provide reserve cooling water storage for the Colstrip Steam Power Plant, Montana. The surge pond was created by construction of a Main Dam and a Saddle Dam across valleys between low, rolling hills. (Plate 2)

The dams are zoned earth-filled embankments, constructed predominantly of locally available borrow material. Physical features of the dams are outlined on the pertinent data sheets. Embankment cross sections for the two dams are shown on Plate No. 6.

Main Dam

The Bechtel Design Report indicates that the 67-foot-high, 1095-foot-long dam has a nearly vertical, impervious central core and cutoff trench extending into bedrock, with a surrounding shell of cohesionless soils. (Plates 4 & 6) Upstream slope protection is riprap with filter bedding, over the entire face. (Photo 3) Internal drainage zones include a chimney and inclined drains, downstream of the core and cutoff trench, respectively. These drains provide seepage relief through a horizontal drainage blanket, discharging to a downstream toe drain.

Materials for the various dam zones were from locally available borrow sources, with the exception of internal drainage and bedding materials which were specially processed. Core materials were clayey silt/silty clay (ML-CL) soils from a source near the west end of the reservoir. Shell materials were fine silty sand or baked sandstone and siltstone (SP-SM) from borrow areas north and west of the dam, or east of Colstrip. Drain-

age and bedding materials were processed from concrete aggregates. Riprap was imported since a hard, durable rock was not locally available.

There is no evidence of settlement, cracking, misalignment or traffic damage on the dam crest. Though most of the exposed upstream slope above water surface was riprapped, no cracking was observed or indicated. However, this exposed portion exhibited some profile irregularities. From approximately 600 feet to 200 feet left of the right abutment, the 1V on 3.5H upstream slope (Photo 4) has been steepened and benched, possibly due to disturbance during subsequent construction of the slurry wall. Riprap does not completely cover the slope face in the benched area. Other irregularities were observed near the left abutment. The 100 feet of upstream slope immediately right of the left abutment has been steepened to about 1V on 1.5H for the upper 10 feet, to accommodate crest widening. Riprap in this area is baked shale material grading from less than 6 inches to greater than 18 inches in diameter. This may have been the material used to widen the crest. Immediately west of the abutment contact along the saddle-service road fronting the emergency spillway considerable wave erosion has occurred (Photo 5).

No cracking or settlement was found on the downstream slope. Runoff has eroded rills 1 to 6 inches deep over some of the slope, where vegetative cover is thin, but has not caused significant deviation from the 1V on 2.5H slopes. There is some minor cutting at the embankment toe. Scattered animal burrows were noted. (Photo 4)

Considerable surface erosion is evident at the left abutment downstream contact. This erosion channel is up to 15 feet wide (Photo 7), and the channel has been partially filled with sand and gravel in an attempt to provide erosion protection. The erosion has continued, undermining this fill (Photo 8) and some of the downstream toe of the slope. Only minor seepage was observed at the right abutment, where extensive construction and post-construction treatment to cutoff seepage has been applied. The downstream slope is well covered with grass with the exception of a few small areas where runoff erosion has occurred.

A groundwater monitoring program, initiated prior to construction and including installation of five observation wells, was designed to monitor the effectiveness of the grout curtain and other seepage control measures, along with the response of the original groundwater regime to imposed conditions. Twenty-eight piezometers and ten additional observation wells were installed in the right abutment area when reservoir filling resulted in substantial leakage. Many of the piezometers are still operational and are monitored periodically by Montana Power Company personnel.

Saddle Dam

The Design Report indicates the 19-foot-high, 800-foot-long dam embankment is constructed of impervious material with a cutoff trench extending into bedrock. (Plates 5 & 6) The upstream slope is protected with riprap on a filter bedding. An inclined drain at the downstream face of the cutoff trench is connected to a horizontal drainage blanket exiting through a filtered downstream toe drain. Embankment materials were obtained from the same sources as for the Main Dam.

There is no evidence of cracking, settlement, or traffic damage in the 19-foot-high embankment crest.

The upstream slope has maintained the design slope of 1V on 2.5 H. Riprap covers the slope face, except in the shoulder areas near the crest. There is no cracking along the slope. The riprap ranges from 12 to 36 inches in diameter.

The downstream slope shows no noticeable variation from the 1V on 2.5H design slope, and there is no cracking or seepage evident. The toe drain was dry at the time of inspection. There is good grass cover, with little erosion, and there are numerous animal burrows.

The abutment contacts are sound. No seepage was observed.

One groundwater observation well was installed downstream from the embankment, prior to construction. Water level at the time of inspection was about 4 feet below ground surface. There were no wet spots observed in the downstream embankment.

2.3.2 Foundation Conditions, Seepage and Drainage

Geologic profiles at the Main and Saddle Dams, shown on Plates No. 4 and 5, respectively, were developed using subsurface information published in the Bechtel Design Report. Field explorations from which the subsurface information was gathered were conducted by Northern Testing Laboratories, Inc. in 1973 and 1974. Subsequent laboratory testing to determine index and engineering properties of representative foundation soil samples was also conducted by NTL. Test results are documented in the aforementioned Design Report.

Main Dam

The subsurface profile along the dam axis shows a thin soil mantle over the gently sloping valley walls. Soil cover in the valley floor reached a maximum depth of 37 feet. These overburden soils are alluvial, interbedded, loose to medium dense, silty, fine sands (SM), firm to stiff sandy and clayey silts (ML), and firm to stiff silty and sandy clays (CL).

Bedrock beneath the damsite is predominantly interbedded sandstone and shale. The sandstone ranges from soft, friable, and weakly cemented, to moderately hard. The softer, more friable sandstones typically occur higher in the bedrock profile. The shales vary from soft and plastic to hard. The McKay coal layer, 8 to 10 feet thick, was encountered between elevations of 3225 and 3235 at both abutments, and also observed to outcrop in the reservoir west of the dam axis. A second coal layer, the Rosebud coal layer, apparently burned out above the dam crest elevation in the abutment areas.

Positive seepage cutoff beneath the embankment was to be provided by an impervious core cutoff trench extending 2 feet into bedrock across the valley floor. Trench depth was to increase to a minimum of 5 feet along valley walls, i.e., abutment contacts. Trench width was to taper from 48 feet on the valley floor, to 20 feet at the abutments. To further minimize underflow, a grout curtain was specified along the dam axis and for a distance of 300 feet into each abutment. The grout curtain was to

seal off the McKay coal layer and weakly cemented sandstones above. The McKay coal outcrop in the reservoir area was also covered with reject from the borrow areas and excavations from the cutoff trench, to provide sealing.

The chronology of reservoir filling, subsequent leakage, and remedial construction are discussed previously. In summary, reservoir filling during early 1975 resulted in substantial groundwater level increases in observation wells downstream and at the right abutment, with accompanying saturation of the abutment area. Remedial measures employed to maintain abutment stability and dam integrity included installation of hydrauger slope drains, additional grouting, and, finally, construction of a concrete slurry cutoff trench. These measures were taken over the course of several attempts at reservoir filling during 1975 and 1976.

The original grout curtain construction required substantially more grouting of the weaker, more permeable sandstones overlying the McKay coal layer in the right abutment area than contemplated. Field observations and geophysical investigations made subsequent to initial reservoir filling and leakage indicated this upper sandstone unit was the primary medium for seepage losses. Therefore, a slurry trench was constructed through the upper sandstone and underlying McKay coal layer.

The extent and cross section of the slurry trench are shown on Plate No. 7. It was to extend to the outlet works, and was to penetrate 2 feet into the competent sandstone beneath the McKay coal layer.

Following completion of the trench in December 1976, surface leakage from the abutment drains has been reduced to approximately 2 gallons per minute at nearly full operating pool level. Seepage losses of 800 to 1000 gallons per minute had been estimated in the right abutment area during operation at full pool elevation without the slurry trench cutoff. Following installation of the trench and reservoir filling, downstream piezometric levels in the right abutment area did not rise, and the abutment area did not become saturated.

This inspection noted minor surface leakage, approximating the 2 gallons per minute flow observed following completion of the slurry trench. This leakage is transmitted by a system of corrugated metal piping along the downstrem toe, into a ditch, and then to a small pond which overflows to a dry well. This system was not part of the original dam design and was probably implemented in conjunction with the post-construction leakage at the right abutment. The reservoir elevation on the date of inspection was 3279.3 feet NGVD, which is is 9.7 feet below the dam crest. Only an isolated trace of seepage was observed near the right abutment contact. No seepage was observed at the left abutment, and the toe drain was dry throughout its length.

Saddle Dam

There is a thin layer of silty fine sand (SM) over sandstone bedrock. The sandstone is generally unweathered, unjointed, and well cemented except near the left abutment where the rock was less well cemented.

The cutoff trench was to have a minimum bedrock penetration of 1 foot, an overall minimum depth of 5 feet, and a uniform trench width of 18 feet. A filter drain was specified.

No seepage was observed on the downstream slope or in the abutment contacts. The toe drain was dry.

Emergency Spillway

The emergency spillway structure, apparently founded on medium hard sandstone bedrock, is in a saddle west of the Main Dam's left abutment. There is about 3 feet of silty sand and weathered sandstone over the bedrock at the site. The approximately 1V on 2H sideslopes along the east side of the unlined stilling basin have become moderately eroded under the action of surface runoff, and there is some sloughing of slope surface materials (Photo 9). There has been some erosion of soil to the sandstone bedrock beneath the flip bucket and behind the wingwalls at the outlet of the chute (Photo 10).

2.3.3 Stability

Stability analyses were performed for the Main Dam only, and were made for an embankment cross section in the deepest part of the valley. Computer programs for the analyses were based on the modified Swedish slip circle method. The cases analyzed, along with their respective required and computed factors of safety as reported in the Bechtel Design Report, are summarized below:

Case	Factor of Safety: Recommended By Guidelines	Factor of Safety: Computed
Upstream Slope:		
Steady Seepage with Maximum Storage Pool (El. 3285), without Seismic Forces	1.5	2.12
Steady Seepage with Maximum Storage Pool (El. 3285), with Seismic Forces (0.05g)	1.1	2.01
Rapid Drawdown from Spillway Crest (El. 3285 to El. 3248)	1.25	1.95
Downstream Slope:		
Steady Seepage with Maximum Storage Pool (El. 3285), without Seismic Forces	1.5	1.55
Steady Seepage with Maximum Storage Pool (El. 3285), with Seismic Forces	1.1	1.28

The strength parameters used for stability analyses were determined from consolidated drained triaxial compression tests made on undisturbed foundation soil samples and remolded embankment materials. The embankment materials were remolded to 95 percent of maximum dry density at optimum moisture content under a compactive effort of 20,000 foot-pounds per cubic foot. The cohesion parameter determined for the various materials was ignored in the analyses.

Additional assumptions germane to the analyses are as follows:

1. Internal drainage provisions depress the phreatic surface to the top of the drainage blanket downstream of the arc.

2. Due to the relatively low permeability of shell materials, no dissipation of pore pressures were assumed for the rapid drawdown case.

3. Pseudo-static earthquake loading used a seismic coefficient of 0.05.

4. Flow nets were constructed using the following ratios of horizontal to vertical permeability based on experience and field and laboratory permeabilities:

   Embankment Materials: $K_h = 4\ K_v$
   Foundation Materials: $K_h = 9\ K_v$

2.4 PROJECT OPERATIONS AND MAINTENANCE

2.4.1 Dam Maintenance Plan

Project maintenance inspections have been made on a regular basis. However, no records or published maintenance plans were available for review.

2.4.2 Reservoir

Normal pool levels fluxuate daily with the power station's cooling requirements. Bechtel's design report called for a normal summer maximum pool elevation of 3281 feet NGVD, and a winter maximum pool elevation of 3285 feet NGVD. Minimum live pool elevation is 3248 feet NGVD. Reservoir records were not available for review. Winter pool elevations are raised by the use of 4-foot-high flashboards on the emergency spillway crest. The original design called for the removal of the flashboards during the summer months. However, this does not appear to have been done, since they were in place at the time of the August, 1980, inspection.

2.4.3 Warning System

There is no formal downstream warning plan in case of impending dam failure.

CHAPTER THREE
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dams supplemented by analysis of the project in terms of recommended guidelines performance standards resulted in the following findings.

3.1.1 Size, Hazard Classification and Dam Safety Evaluation

The main dam is 67 feet high and the Saddle Dam is 19 feet high. Together they impound 3540 acre-feet at the Saddle Dam crest elevation of 3288.5 feet NGVD. In accordance with inspection guidelines the project is intermediate in size with a high downstream hazard potential rating. The recommended spillway design flood (SDF) for this project is the full PMF.

Flood routing studies show that the dam safely passes the PMF developed for this inspection provided that initial reservoir elevations are below about 3284.0 feet NGVD at the onset of the PMF. However, with the initial reservoir elevation at 3285.0 feet NGVD, routing of the full PMF shows that the low point in the dams crest is overtopped for a short period of time. Because of the remote possibility of this scenario and the very conservative nature of the routing input we do not recommend further hydrologic studies. Consider restoring minimum dam crest on the Saddle Dam to elevaton 3289.0 feet NGVD to further enhance safety. Based on our review of the post-construction stability analysis performed by Bechtel and the visual inspection of the dam embankments, it is our judgment that the project may meet inspection guidelines for stability. However, the position of the fully developed phreatic surface was not determined in the inspection.

3.1.2 Outlet Works

Water levels at the time of inspection prohibited inspection of the outlet works. However, the outlet works are in operation almost continuously, and functional impairment of gates, valves, etc., would come to the immediate attention of operating personnel. A thorough inspection of the conduit beneath the dam embankment should be made to determine condition.

3.1.3 Emergency Spillway

The emergency spillway concrete was observed to be in good condition with no evidence of settlement, cracking, or spalling. Surface runoff has eroded backfill adjacent to the sidewalls in the exit channel and around the wingwalls of the flip bucket. Backfill materials immediately downstream from the end of the chute are on a steep slope, and appear to be loosely consolidated. Some surface erosion has occurred on this slope as well as on the sides of the unlined stilling basin downstream. Although the end sill of the flip bucket appears to be founded on hard sandstone, this could not be confirmed. Flow through the emergency spillway would rapidly erode the consolidated backfill and could expose and possibly undermine the outlet end of the chute. However, this would not damage or otherwise endanger the dam embankments because the spillway is not adjacent to either one.

3.1.4 Reservoir Storage and Spillway Capacity

The reservoir has a surface area of 140 acres and a storage of 2280 acre-feet at emergency spillway elevation of 3281.0 feet NGVD. Approximately 1260 acre-feet of surcharge storage is available in the reservoir between the emergency spillway and the dam crest, elevation 3288.5 feet NGVD. The discharge capacity of the emergency (chute) spillway is 2820 c.f.s. with out flashboards, and 850 c.f.s. with flashboards, with the reservoir at dam crest. For comparative purposes the total flood volume of the 6 hr., 24 hr., 48 hr., and 72 hr., PMF flood volume with zero infiltration is 925 acre-feet, 1185 acre-feet, 1280 acre-feet, and 1340 acre-feet respectively.

3.1.5 Dams Embankment

Main Dam

No cracking or differential movements along the embankment crest or slopes, and no traffic damage of consequence on the crest service road was observed. Some scattered animal burrows were observed over the downstream slope.

The upstream slope between the outlet structure and the right abutment has been disturbed, apparently by slurry cutoff trench construction. Slope cross section and riprap cover were not restored to their original lines. The steepened baked shale (scoria) covered slope at the left abutment deviates from the original project design, but appears stable.

Wave erosion is undercutting the saddle-service road between the left abutment and the emergency spillway. Precipitation runoff has caused surficial sloughing on the stilling basin sideslopes, erosion along the left abutment contact, minor rilling on the downstream slope, and some cutting of the downstream toe. Erosion has also caused a loss of material beneath the spillway channel flip bucket and behind the spillway wingwalls.

The concrete slurry trench cutoff has reduced seepage through the right abutment. Seepage quantities observed at horizontal slope drains in the right abutment were minor and about the same as immediately after completion of the wall. No other seepage of consequence was evident along the dam.

Saddle Dam

No settlement, misalignment, or cracks were observed. The upstream slope was generally well covered with riprap except along the shoulder of the service road. The scoria-surfaced service road across the dam crest has no apparent deficiencies. Numerous animal burrows were observed on the downstream slope, however, the slope was well covered with grass vegetation.

No seepage was noted on the downstream slope or at the abutment contacts, and the toe drain was dry.

3.1.6 Stability

The case analysis procedure and criteria for stability of the Main Dam embankment used by Bechtel are in accordance with Recommended Guide-

lines for Safety Inspection of Dams (Ref. 1). The resulting factors of safety meet or exceed the criteria.

Consolidated drained shear strength parameters determined by triaxial compression testing were used in the analyses. Although parameter selection is not in strict accordance with The Guidelines for the use of shear strength envelopes averaged with or limited by consolidated undrained test results, the parameters used are consistent with current practice. In addition, cohesion was ignored in the calculation of safety factors.

The ratio of horizontal to vertical permeability for embankment soils used to construct flow nets is not in accordance with the Corp of Engineers suggested minimum of $K_h/K_v = 9$. However, the ratio selected was based on experience and permeability testing data.

The seismic coefficient selected for use in the pseudo-static earthquake loading analyses complies with Corp of Engineers recommendations for Seismic Zone I.

3.1.7 Operations and Maintenance

There is no formal operation and maintenance plan. The project primarily serves as a surge pond for the power plants cooling system. Therefore, the project is visited almost daily by Montana Power Company personnel. Maintenance is performed as needed.

3.2 RECOMMENDATIONS

1. Prepare an emergency warning plan in case of impending dam distress and coordinate with the City of Colstrip.

2. Develop a written dam maintenance plan to provide for prompt repair of the dams and appurtenances to insure their safety and integrity.

3. Modify the area immediately below the emergency spillway outrun to prevent excessive erosion during possible flow conditions.

4. Repair erosion damage around the spillway channel, wingwalls and flip bucket, and stilling basin sideslopes. Inspect and repair or clean the pipe drains in the emergency spillway chute.

Main Dam

5. Continue monitoring piezometers and observation wells in the right abutment and downstream of the dam. Monitoring data should be periodically reviewed by a qualified geotechnical engineer.

6. Repair runoff erosion damage on the downstream slope at the left abutment contact.

7. Provide riprap along the saddle-service road between the left abutment and emergency spillway.

8. Improve vegetative cover on the downstream slope where needed.

9. Repair runoff erosion along the downstream toe of slope.

<u>Saddle Dam</u>

10. Monitor downstream piezometric level periodically. Data should be reviewed by a qualified geotechnical engineer.

11. Repair minimum dam crest to elevation 3289.0 feet NGVD, (assuming spillway flashboard crest is 3285.0 feet as designed)

<u>Both Dams</u>

12. Implement a program to eliminate burrowing animals.

13. Conduct inspection of the Castle Rock Dams at least every 5 years by qualified engineers experienced in earth dam design, construction, and operation and maintenance.

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10. National Weather Service, "Interim All Season Probable Maximum Precipitation Estimates, Missouri River Basin West of 105th Meridan," January, 1980.

PHOTOS


DIVERSION DAM
WEST DRAIN
CREEK
N
TO FORSYTH
MOBILE HOME PARK
COAL MINE
EAST DRAIN
OUTLET WORKS
LIGHT INDUSTRY
CASTLE ROCK
TOWNSITE EXPANSION
FUTURE TOWNSITE
EXPANSION
WATER TREATMENT PLANT
SADDLE DAM
B. N. RAILROAD SPUR
SCHOOL
MT. HWY. 19
COAL FIRED POWER PLANTS
OPERATING
UNDER CONST.

PHOTO 1
Spillway Outlet
(Note erosion potential)

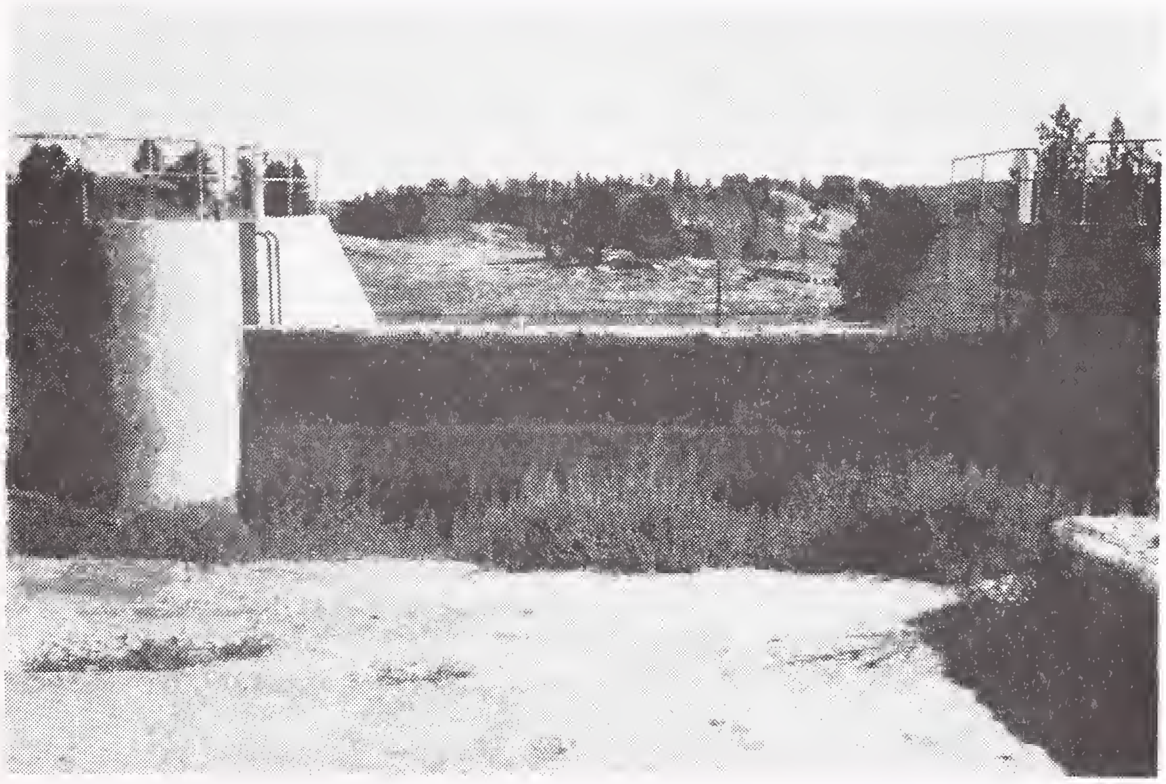


PHOTO 2
Spillway Inlet

PHOTO 3
Upstream Face of Main Dam Showing Riprap

PHOTO 4
Upstream Face of Main Dam Showing Steepened Section

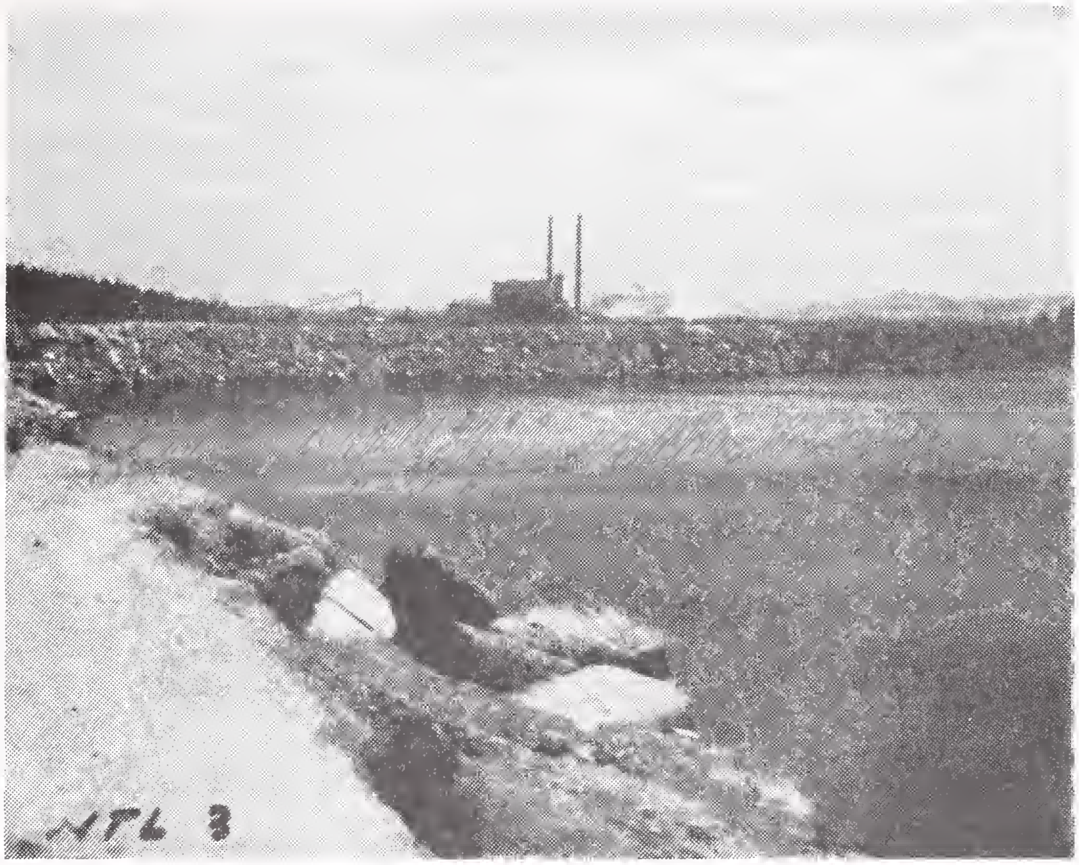


PHOTO 5

Wave Erosion - Main Dam

PHOTO 6

Animal Burrows - Main Dam

PHOTO 7

Left Abutment Downstream Erosion

PHOTO 8

Left Abutment Erosion Undermining Backfill

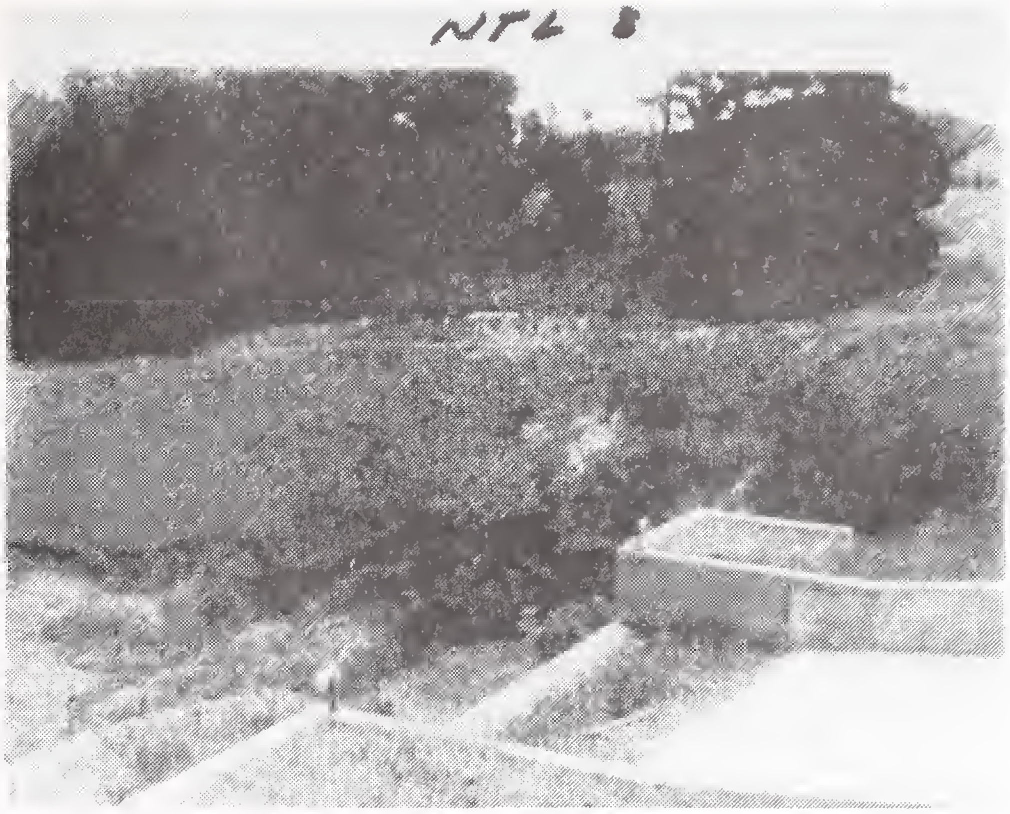


PHOTO 9

Emergency Spillway Erosion Downstream from Stilling Basin

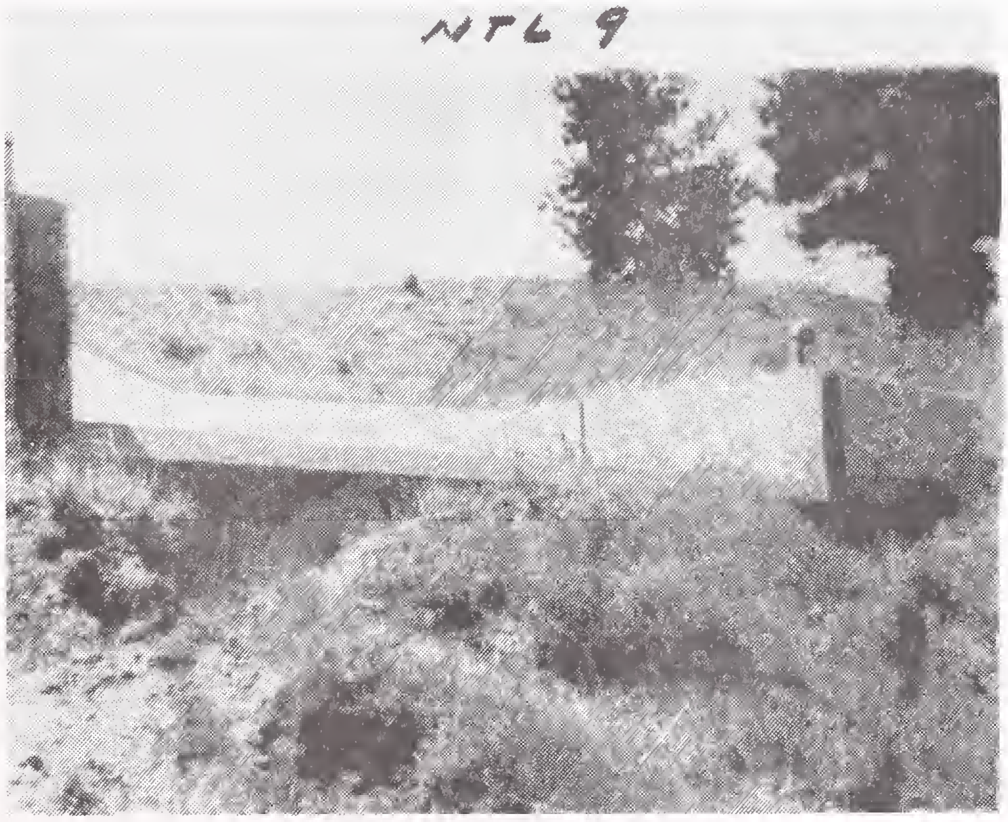
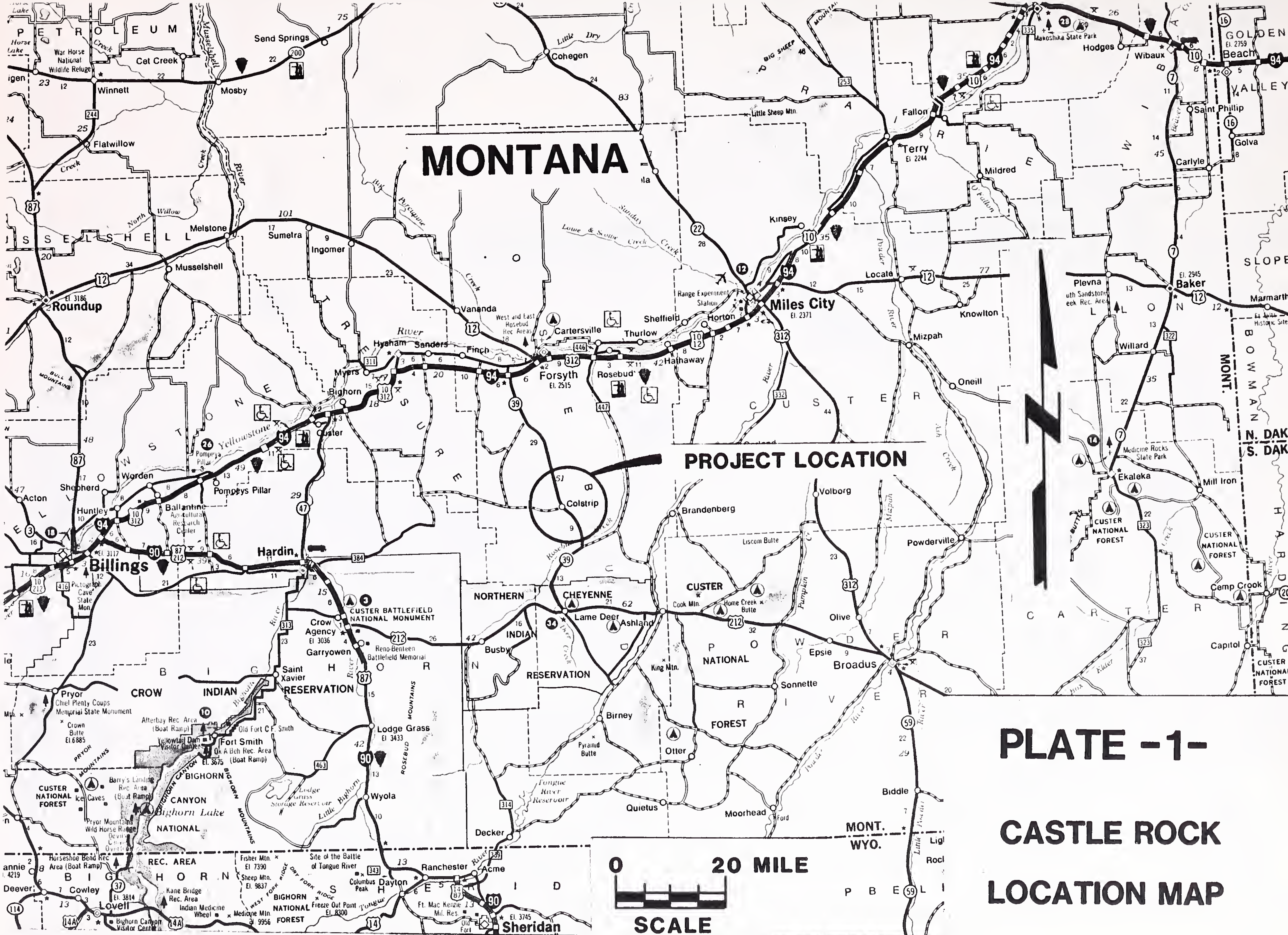


PHOTO 10

Erosion Beneath the Flip Bucket and Behind the Wing Walls at the Emergency Spillway

PLATES


MONTANA
PROJECT LOCATION
Colstrip
Miles City
Forsyth
Billings
Hardin
Broadus
Baker
Sheridan
0 20 MILE
SCALE
MONT.
WYO.
N. DAK
S. DAK
PLATE -1-
CASTLE ROCK
LOCATION MAP

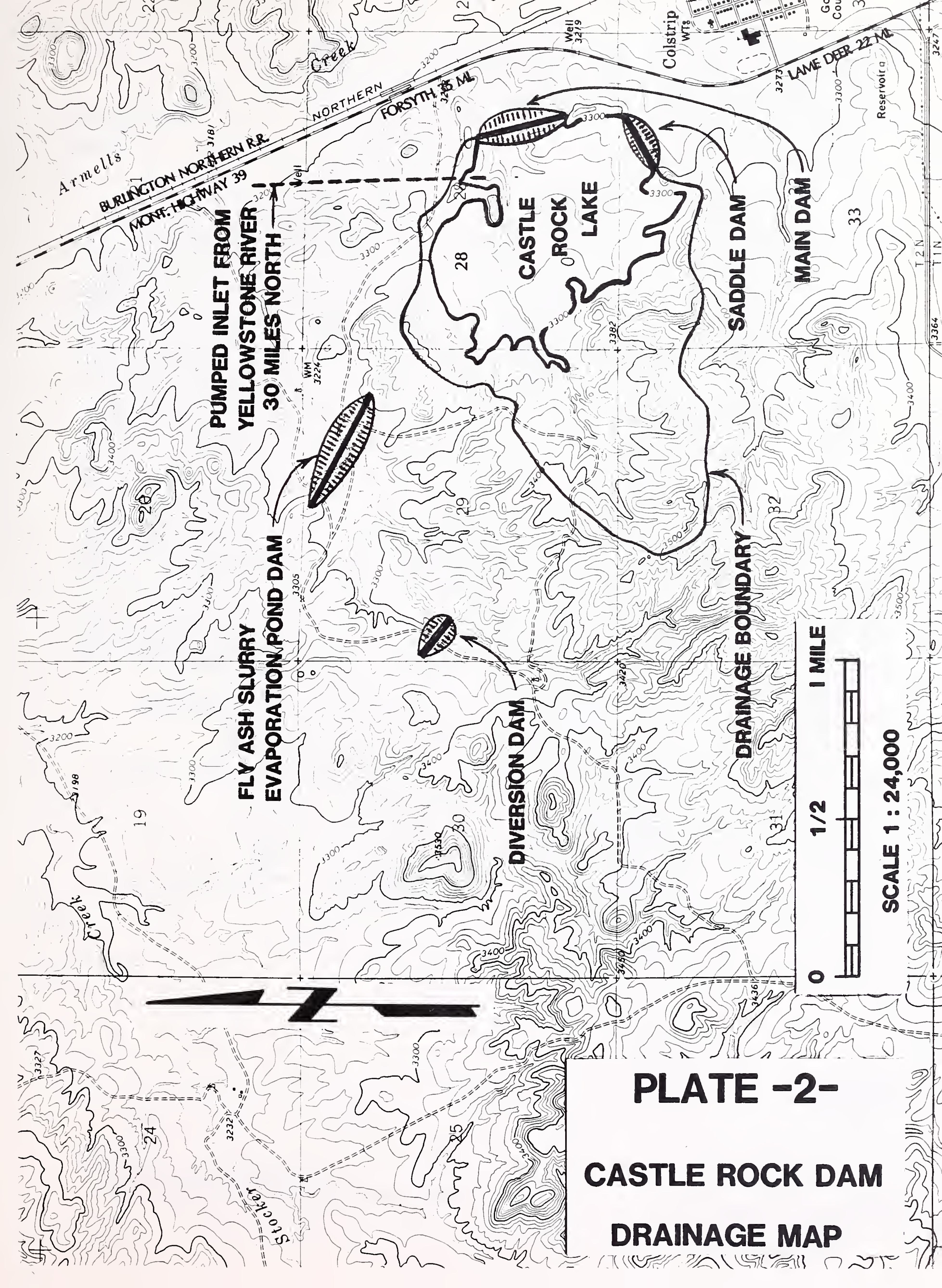
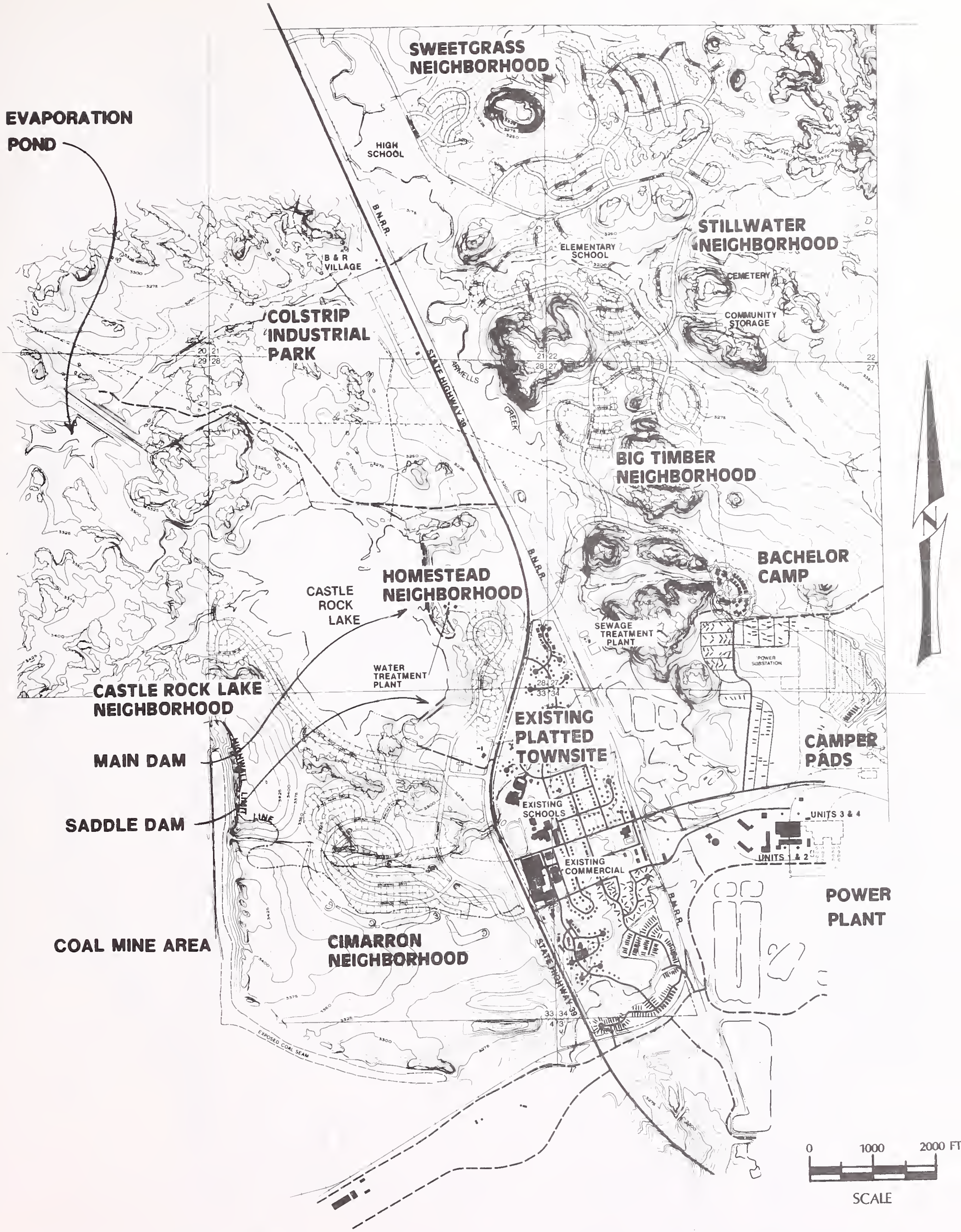


PLATE -2-

CASTLE ROCK DAM

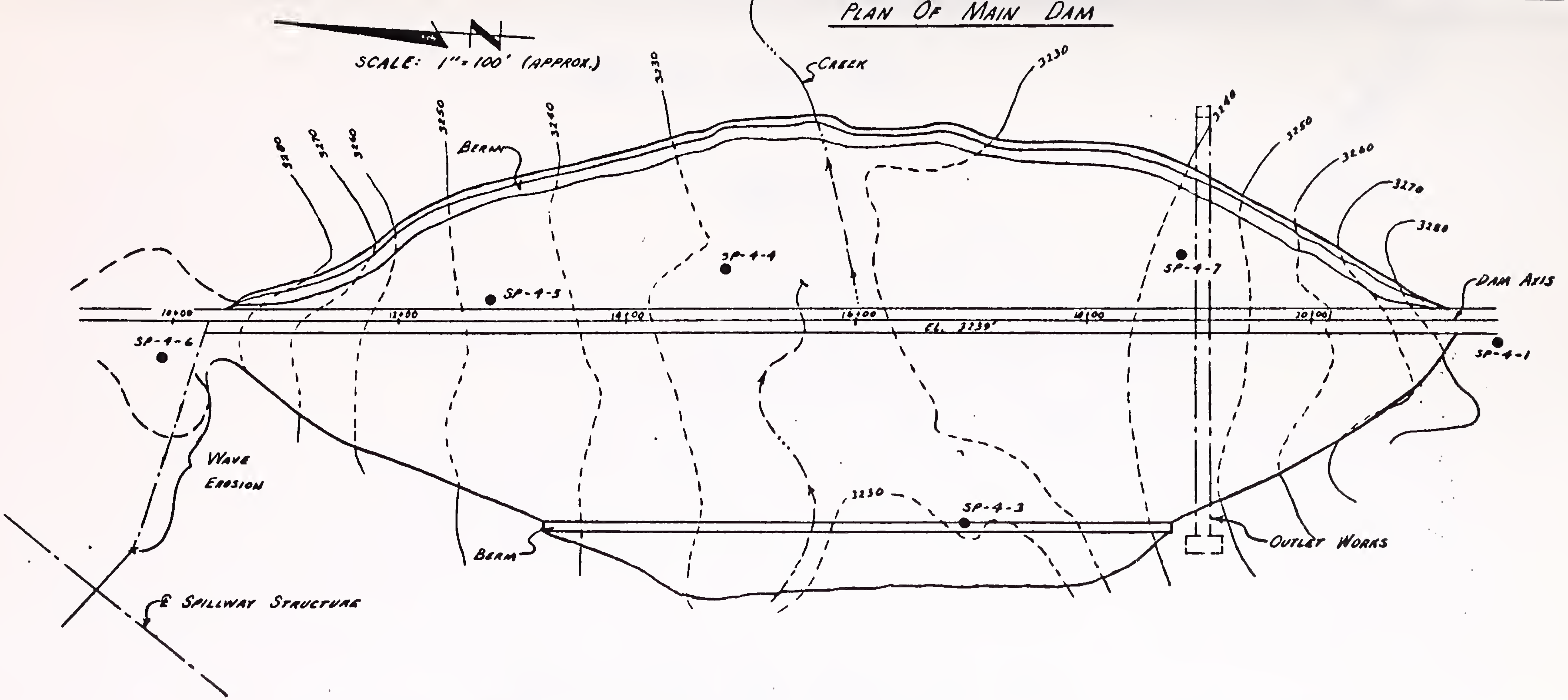
DRAINAGE MAP

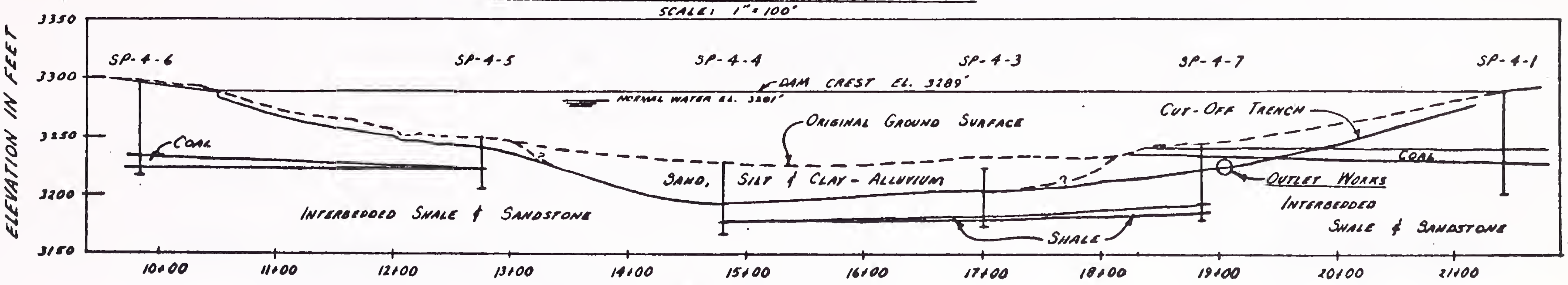


NOTE: COLSTRIP EXPANSION UNDER CONSTRUCTION 1979 - 1981

PLATE -3-

COLSTRIP TOWNSITE EXPANSION





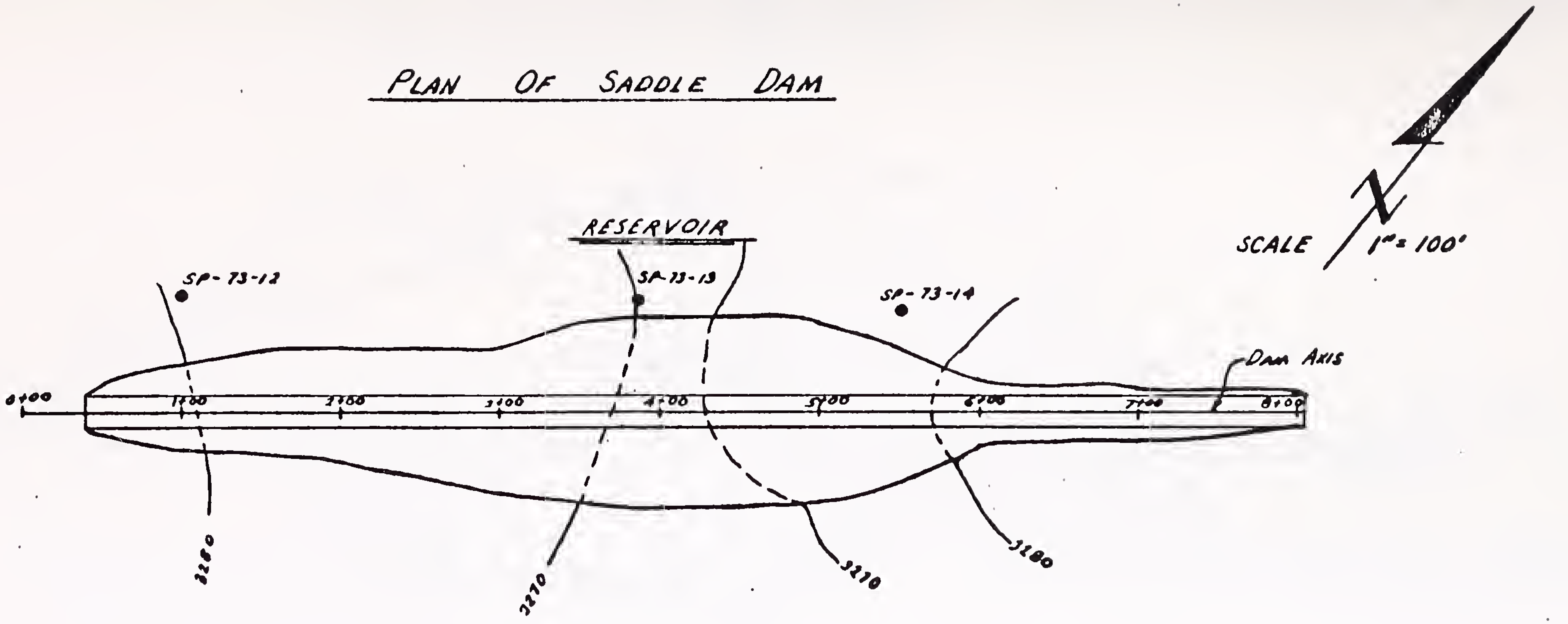
NOTE: ALL INFORMATION ON THIS PLATE HAS BEEN TAKEN FROM THE COLSTRIP PROJECT, MONTANA, SURGE POND DAM DESIGN REPORT PREPARED BY THE BECHTEL POWER CORPORATION (JULY 22, 1974).

PLATE -4-

CASTLE ROCK

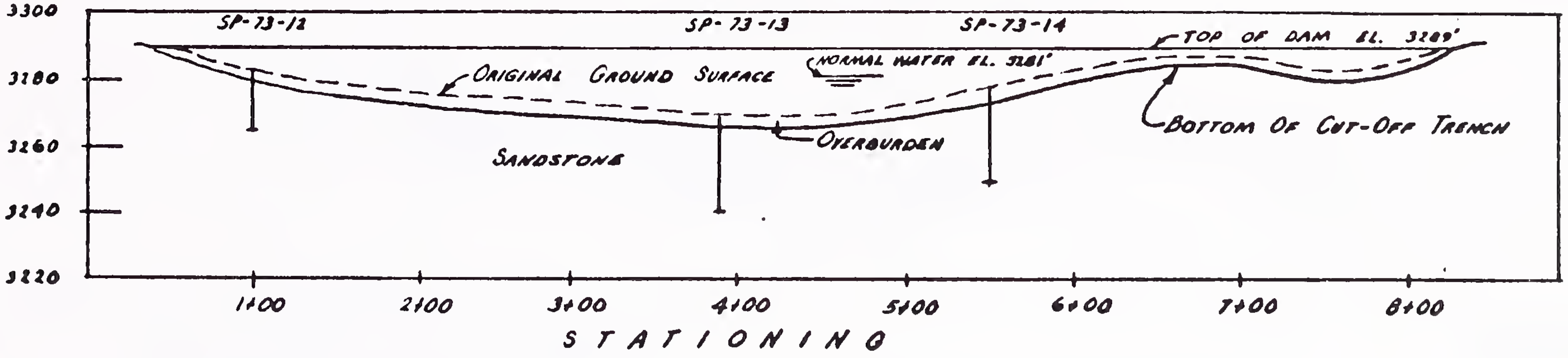
MAIN DAM

PLAN OF SADDLE DAM



GEOLOGIC PROFILE ALONG SADDLE DAM AXIS

VERT. SCALE: 1" = 50' HOR. SCALE: 1" = 100'



NOTE: ALL INFORMATION ON THIS PLATE HAS BEEN TAKEN FROM THE COLSTRIP PROJECT, MONTANA, SURGE POND DAM DESIGN REPORT PREPARED BY THE BECHTEL POWER CORPORATION (JULY 22, 1974).

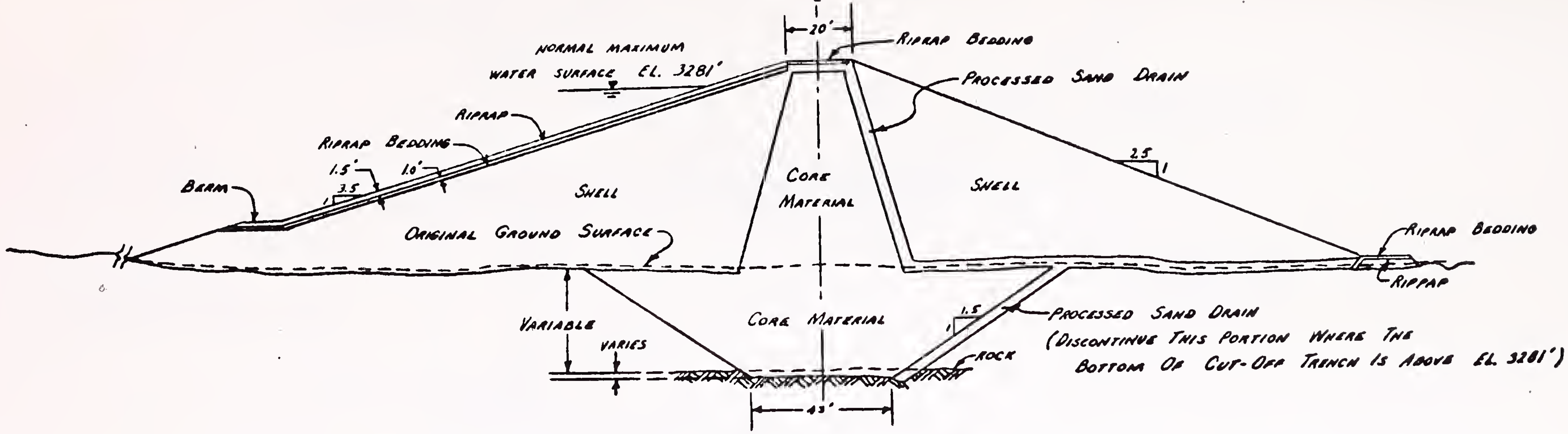
PLATE -5-

CASTLE ROCK

SADDLE DAM

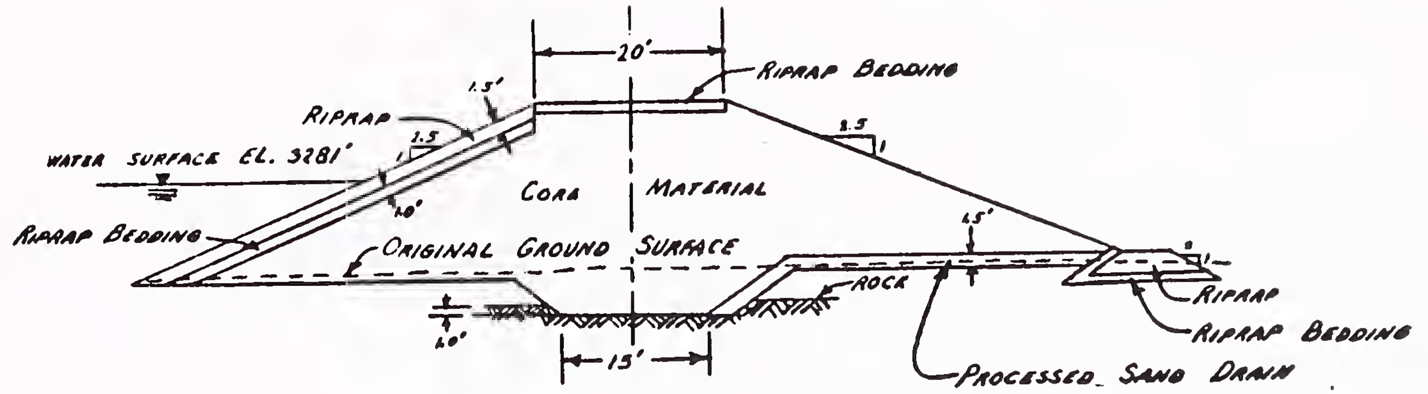
CROSS-SECTION OF MAIN DAM

SCALE: 1" = 40'



CROSS-SECTION OF SADDLE DAM

SCALE: 1" = 20'



NOTE: ALL INFORMATION ON THIS PLATE HAS BEEN TAKEN FROM THE COLSTRIP PROJECT, MONTANA, SURGE POND DAM DESIGN REPORT PREPARED BY THE BECHTEL POWER CORPORATION (JULY 22, 1974).

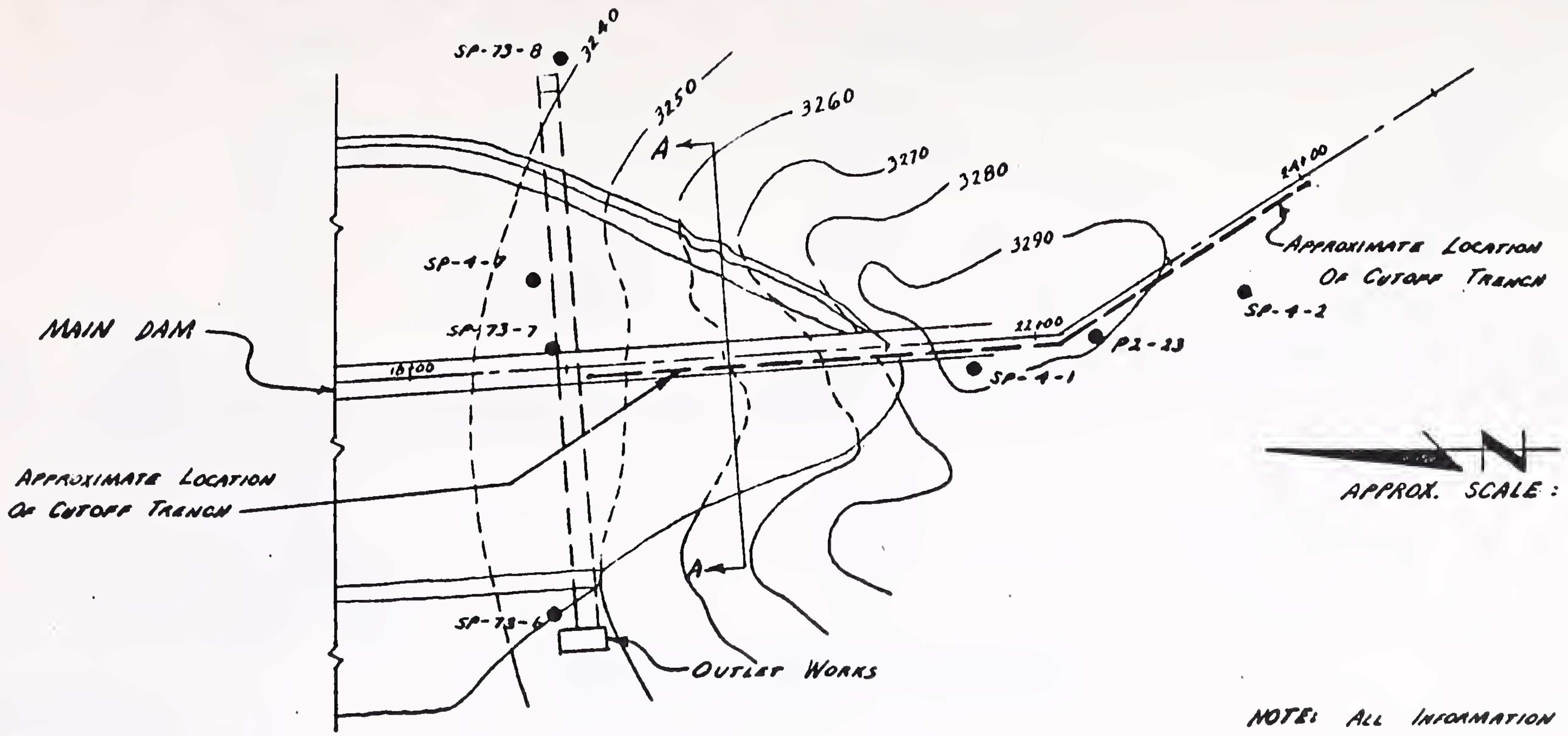
NOTE : DAM CREST ELEV. 3289.00'

PLATE -6-

CASTLE ROCK

EMBANKMENT SECTIONS

CONCRETE SLURRY CUTOFF TRENCH



NOTE: All Information On This Plate Has Been Taken From Construction Drawing No. C1-826, Surge Pond Dam Cutoff Trench, Prepared By The Bechtel Power Corporation (September 16, 1976).

SECTION A-A

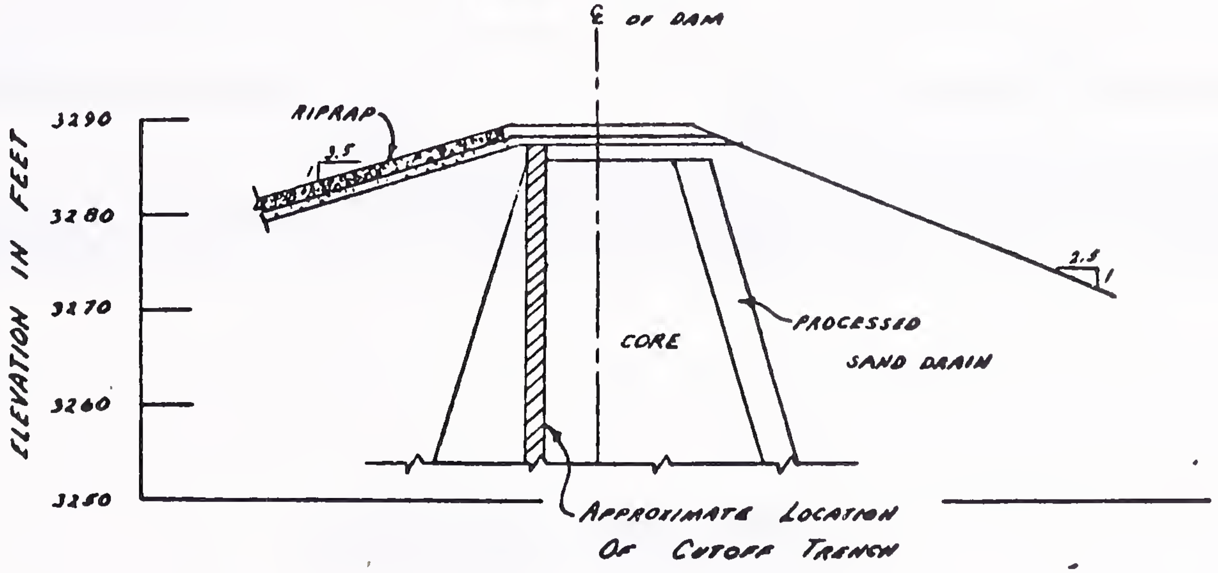
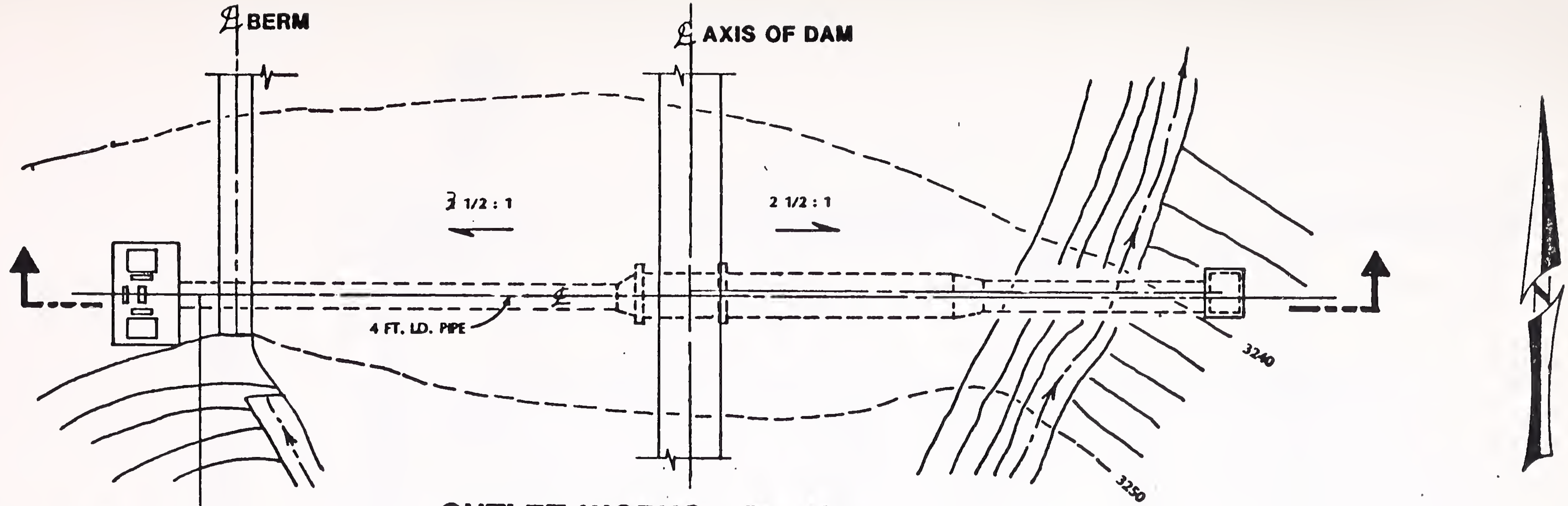
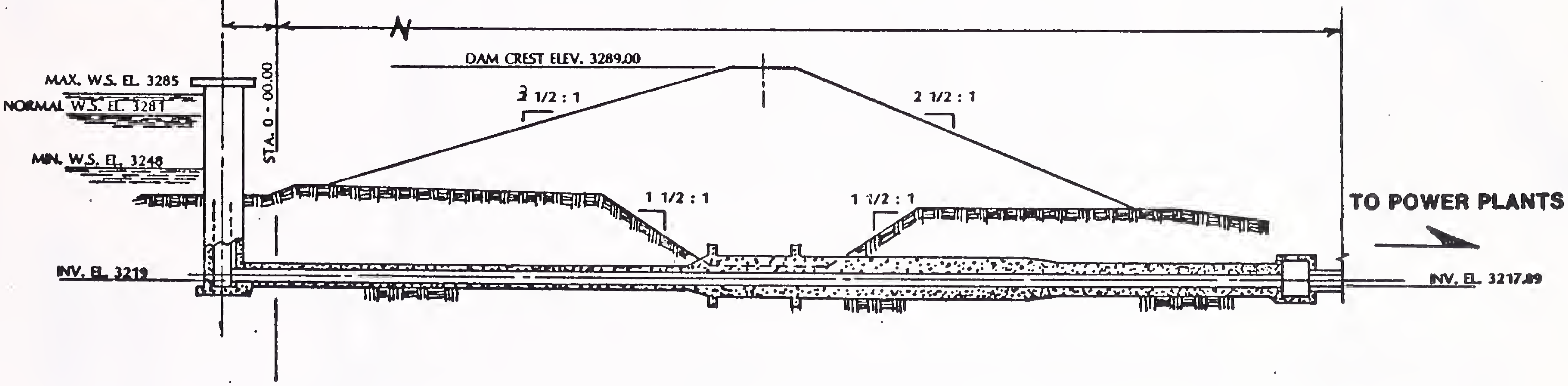


PLATE -7-

CASTLE ROCK SLURRY TRENCH



OUTLET WORKS - PLAN



PROFILE - SECTION

PLATE -8-

CASTLE ROCK DAM

OUTLET WORKS

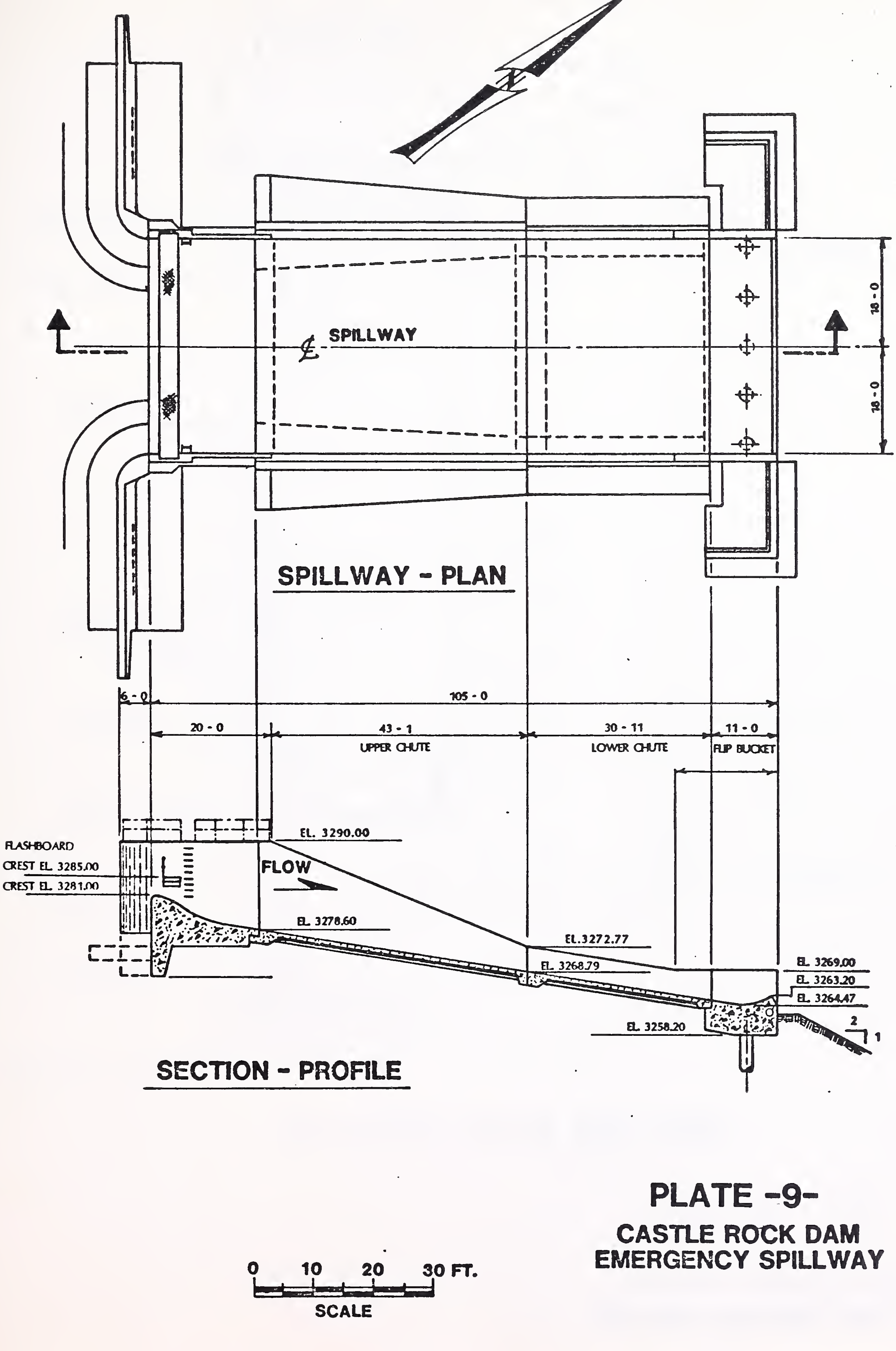


PLATE -9-

CASTLE ROCK DAM EMERGENCY SPILLWAY

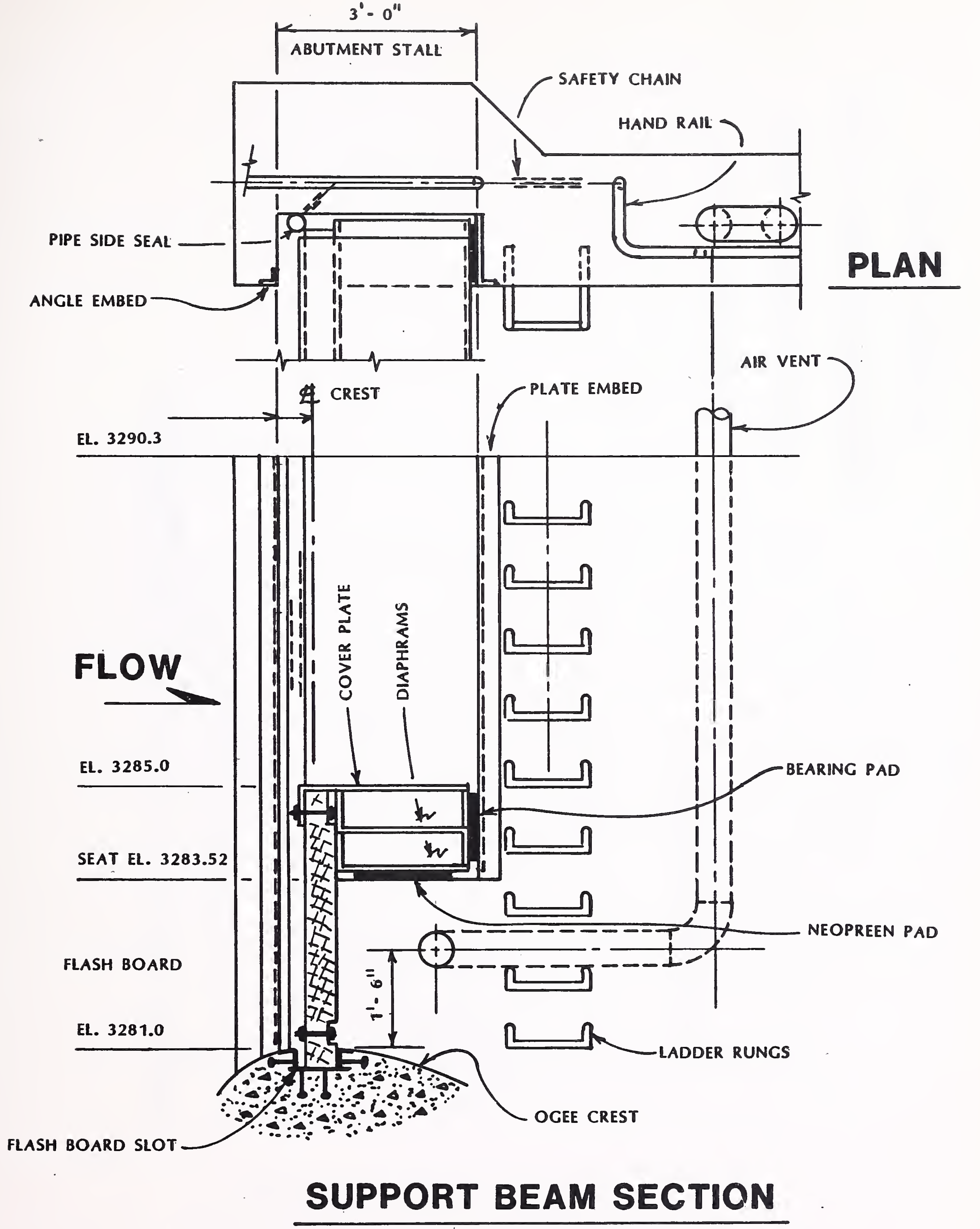
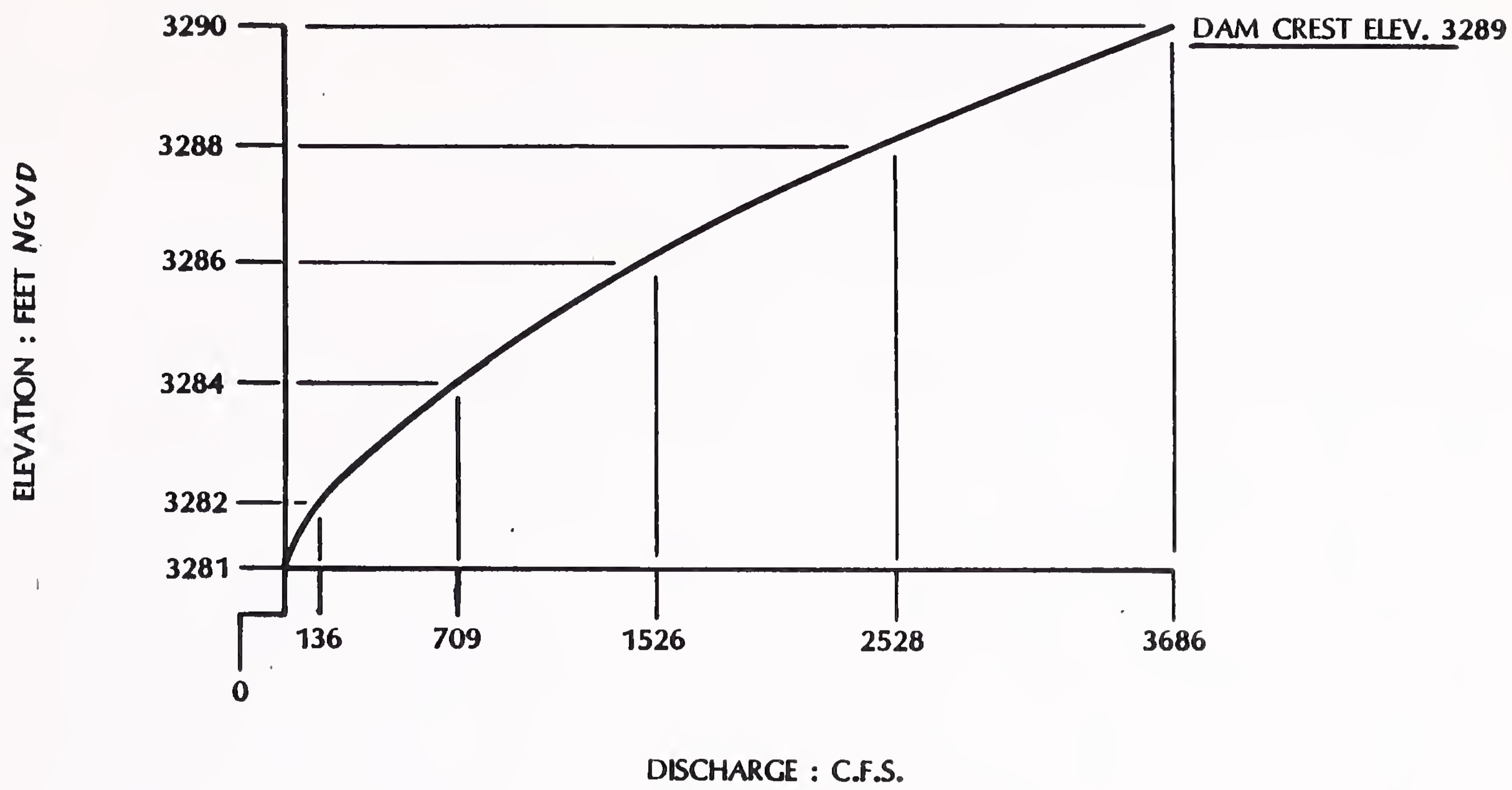


PLATE -10-

CASTLE ROCK DAM
FLASH BOARD DETAIL



NOTE : BECHTEL DESIGN CURVE 3/74

PLATE -11-

CASTLE ROCK DAM

EMERGENCY SPILLWAY

RATING CURVE

CORRESPONDENCE

MONTANA POWER COMPANY mpc GENERAL OFFICES: 40 EAST BROADWAY, BUTTE, MONTANA 59701 • TELEPHONE 406/723-5421

ROBERT J. LABRIE
VICE PRESIDENT
ENGINEERING AND TECHNOLOGY

May 12, 1981

Department Of The Army
Seattle District Corps Of Engineers
P O Box C-3755
Seattle, WA 98124

ATTN: Mr Sidney Knutson, PE
Assistant Chief
Engineering Division

RE : Colstrip Units #1 and #2
File 8680-C-38
Surge Pond Dam
Phase I - Inspection Report (Final Draft)
National Dam Safety Program

Gentlemen:

We have reviewed the above referenced report transmitted to us on April 21, 1981, and have the following comments:

1. In the Pertinent Data section, the purpose of the reservoir is incorrectly stated as providing 10 days of summer storage and 50 days of winter storage for four (4), coal-fired, power generating stations. This should read 18 days of summer storage and 24 days of winter storage for four (4) generating stations.

2. In the Pertinent Data section, it is incorrectly stated that the grout curtain was subsequently installed. The grout curtain was included in the original design and construction and was subsequently expanded. This expanded grout curtain was then supplemented with the installation of a concrete slurry wall.

3. The concrete slurry wall in the left abutment is not included in the report. Only the one in the right abutment is mentioned.

4. The results of the PMF routing studies performed by CSSA do not agree with the studies performed for the Montana Power by Bechtel in 1974. Only the study for one case can be compared directly. This case assumes the flashboards are in place, giving a spillway crest of 3285, and a water surface elevation of 3285 at the onset of the PMF. The results are summarized below:

	CSSA	Bechtel
Peak Inflow	19,160 cfs	3,080 cfs
Max PMF Level	3289.16	3288.60
Design Freeboard	Overtopped	0.4 feet

5. As a result of their studies, CSSA states that overtopping of the saddle dam would not occur if the crest was raised to Bechtel's design elevation of 3290. Bechtel's design elevation is 3289, not 3290.

6. We would like to point out that as a result of their studies, Bechtel recommended filling the reservoir no higher than 3284 (one foot below the top of the flashboards) to prevent encroaching on design freeboard. The Montana Power will ensure that the operating procedures outlined by Bechtel are adhered to.

7. The operating procedure developed by Bechtel calls for removal of the flashboards from March through September. The PMP used for developing the PMF results from a summer time thunderstorm thus making the occurance of the PMF while the flashboards are in place highly unlikely assuming the reservoir is operated as designed.

8. The intent of the inspection was to determine if the dam constitutes a hazard to human life and property. The USCE guidelines state that the engineer-in-charge will give his opinion of the significance, with regard to safety, of any deficiencies in his assessment of the dam. Recommendations 3, 5, 6, 7, 8, 9, and 11 contained in the CSSA report are not discussed in this light. In any event, The Montana Power Company will rectify these deficiencies in the course of normal maintenance.

Very truly yours,

Robert J Labrie

RJL/EWP/mm/B:3

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

May 13, 1981

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Attn: Ralph Morrison

Dear Ralph:

Re: Christian, Spring, Sielbach & Associates Dam Safety Inspection Report of Castle Rock Dam (MT-1982) and Castle Rock Saddle Dam (MT-3146)

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for the opportunity to review and comment on the final draft report on Castle Rock Dam and Castle Rock Saddle Dam.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau

RB:AT:lz